AD-A099 527 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CT F/G 13/2
TEST AND EVALUATION OF THE TRECAN INCINERATOR.(U)
MAR 81 M D LAYNE
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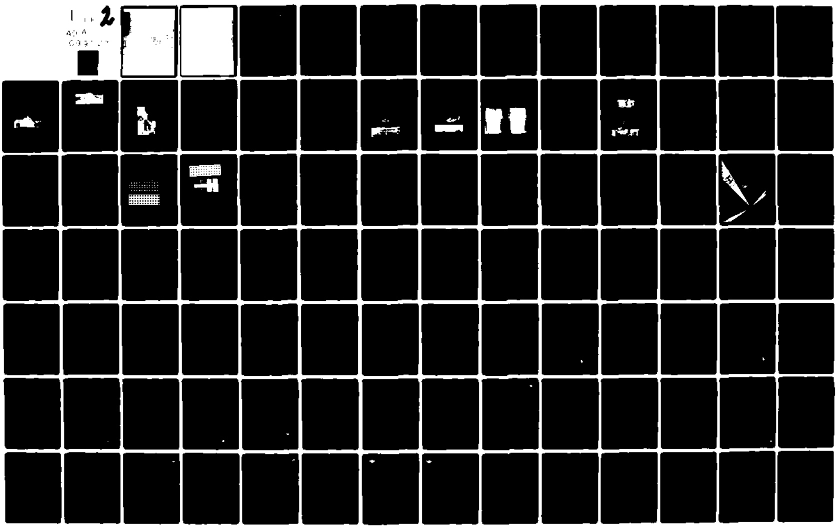

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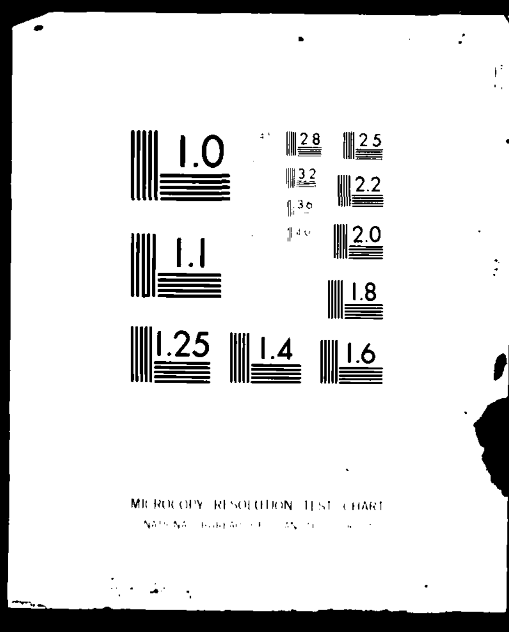

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Technical Report Documentation Page

1. Report No.	2. Government Accession No. AD-A099 527	3. Recipient's Catalog No.
4. Title and Subtitle (6) TEST AND EVALUATION OF THE TRECAN INCINERATOR. (11)	5. Report Date Mar[redacted]81	
	6. Performing Organization Code	
	8. Performing Organization Report No. CGR&DC 3/81	
7. Author(s) (10) M. D. LAYNE		
9. Performing Organization Name and Address United States Coast Guard Research and Development Center Avery Point Groton, Connecticut 06340 (12) 112	10. Work Unit No. (TRAIS) 4153	
	11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Department of Transportation United States Coast Guard Office of Research and Development Washington, DC 20593 (14) CGR/DC-3/81	13. Type of Report and Period Covered 9 FINAL REPORT	
	14. Sponsoring Agency Code	

15. Supplementary Notes

Performed at the U.S. Coast Guard Fire and Safety Test Detachment under technical control of the U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut.

16. Abstract

The Trecan incinerator is an air deliverable open pit incinerator designed to dispose of oily debris recovered as part of an oil spill cleanup operation. What to do with this recovered debris is a critical problem especially in the case of spills occurring in geographically isolated regions. This project succeeded in determining what precautions were necessary for safe and efficient loading of debris, how to minimize the amount of visual emissions, and the incinerator's suitability for Coast Guard HH3F helicopter transport.

The conclusions drawn from the test and evaluation are: (1) the Trecan incinerator can dispose of 1000 lbs of oily debris per hour, (2) the loading chute is an inefficient and hazardous method of dumping debris into the combustion chamber, (3) the incinerator components and sections are durable, (4) the addition of water to the oily debris considerably reduces the amount of visual emissions, and (5) transport and assembly by Coast Guard HH3F helicopter is impractical.

17. Key Words incinerator, overfire air plenum, refractory material, oil emulsions	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

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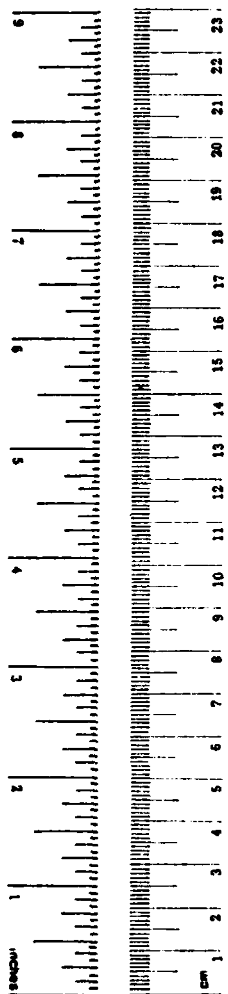
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

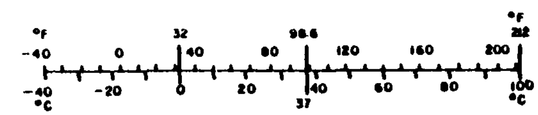
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

1.1 Background

Disposal of oil and debris recovered as part of an oil spill cleanup operation has been identified as a critical problem in many instances. This is particularly true in the case of Arctic spills or in other geographically isolated cases. The development of an air-deliverable open pit incinerator designed and built by Trecan, Ltd., of Mississauga, Ontario, has been followed by the Coast Guard for some time as one possible approach to the disposal problem.

The Coast Guard Research and Development (R&D) Center was requested to conduct an evaluation of the Trecan incinerator at the Fire and Safety Test Detachment (F&STD) by Commandant (G-DMT-4) in July 1979. As a result, a test and evaluation of the incinerator was accomplished in July 1980. This report reviews the effort which was intended to provide test data and detailed first-hand Coast Guard observations, evaluations, and judgements.

The air portable open pit incinerator, built for Fisheries and Environment Canada, was designed to burn oil-soaked combustible debris in Arctic regions and geographically remote or isolated areas. The incinerator components are simplistic in design and are fabricated from materials which are readily available. It was envisioned that such an incinerator could be constructed near the scene of an oil spill incident thereby eliminating the need of stockpiling incinerators at central locations. Assembly of these components after construction could be effected by the helicopter used in transporting the components to the immediate scene.

An initial incinerator evaluation was conducted by Energetex Engineering, Waterloo, Ontario, to establish ease of field assembly, the capacity of the combustion air system and fuel consumption rate of the diesel engine powering the blower. They observed smoke emissions and firebox temperatures monitored at two different feed rates. Their primary recommendation was that the quantity of refractory material used be reconsidered in future designs. The incinerator appeared to be well suited for disposing of municipal wastes at a permanent installation in small towns or villages. For the purposes of air transport into the Arctic, however, it was felt that the overall weight of the unit would be a critical factor that would result in expensive transport costs as well as significant handling and transport difficulties.

An evaluation of the Trecan incinerator was performed in August 1979 by the Prairie Regional Oil Spill Containment and Recovery Advisory Committee (PROSCARAC), Edmonton, Alberta. Representatives from Commandant (G-D) and the Coast Guard R&D Center attended as observers. The conclusion drawn by PROSCARAC was that the incinerator could not dispose the quantities of debris created in a small oil spill as rapidly as desired. A large open earthen pit could be sized to suit the quantity of debris to be incinerated and eliminate the necessity of transporting the massive combustion chamber.

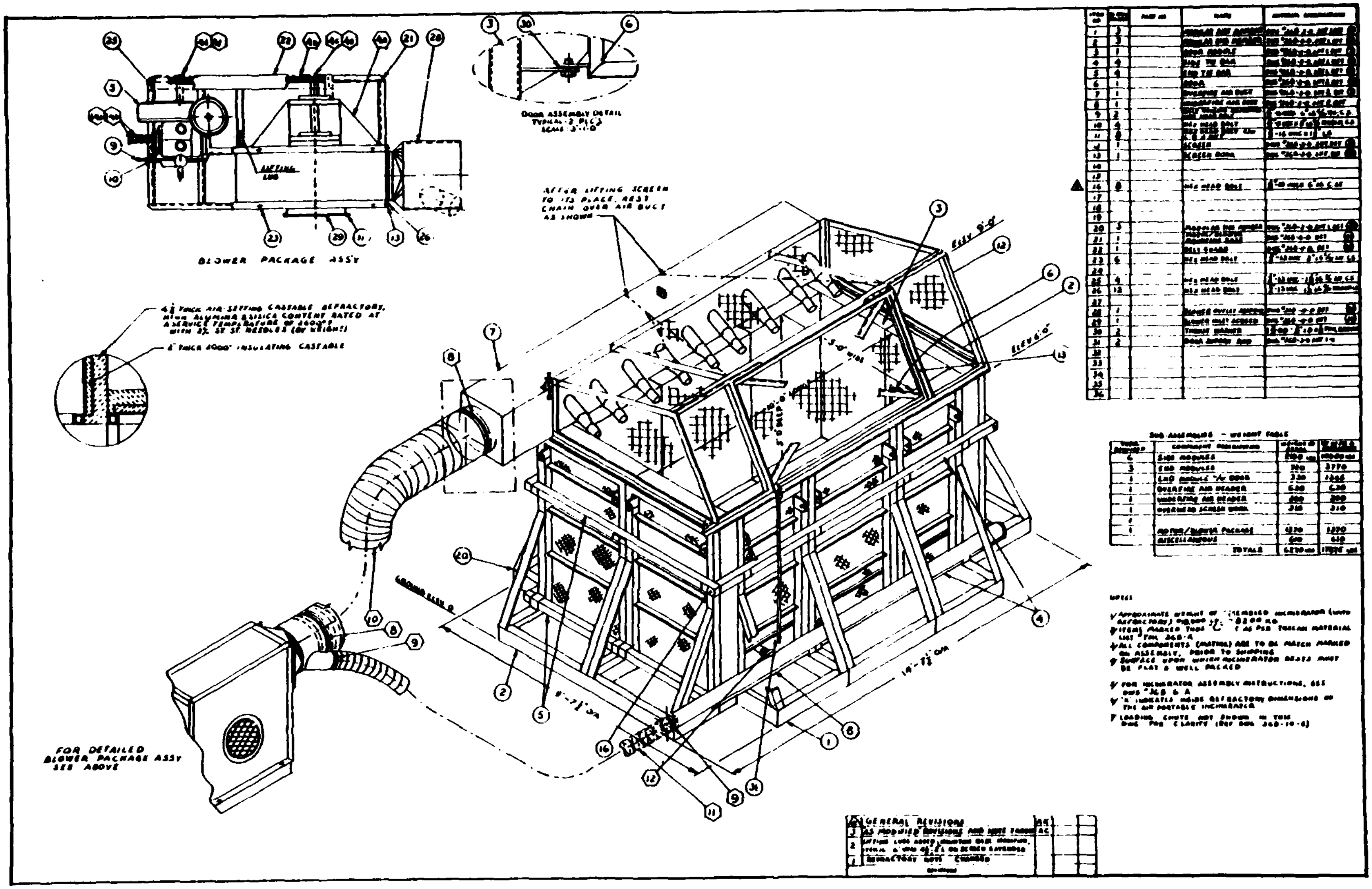


FIGURE 1

Trecan Incinerator

1.2 Objectives

The project objectives were:

a. To determine the feasibility of portable incinerators as an oil debris disposal method; and

b. To determine, in particular, the applicability of the open pit, one ton per hour capacity, Trecan, Ltd., incinerator to Coast Guard needs.

The test and evaluation (T&E) which is the subject of this report was conducted to satisfy these two objectives.

1.3 Scope

Included in the test and evaluation effort was the investigation of what effect debris type, amount of combustion air, and disposal rate had on the concentrations of NO_x, SO_x and particulate emissions. Incinerator operations were examined to determine precautions necessary for safe and efficient loading of debris. Noise levels and total heat flux were monitored in the immediate work area.

The integrity of the refractory material was evaluated. Incinerator components were scrutinized for their adequacy in providing utility, durability, transportability, and convenient assemblage. The air transport and assemblage of the Trecan incinerator using a HH3F helicopter was videotaped on the final day of the test and evaluation series.

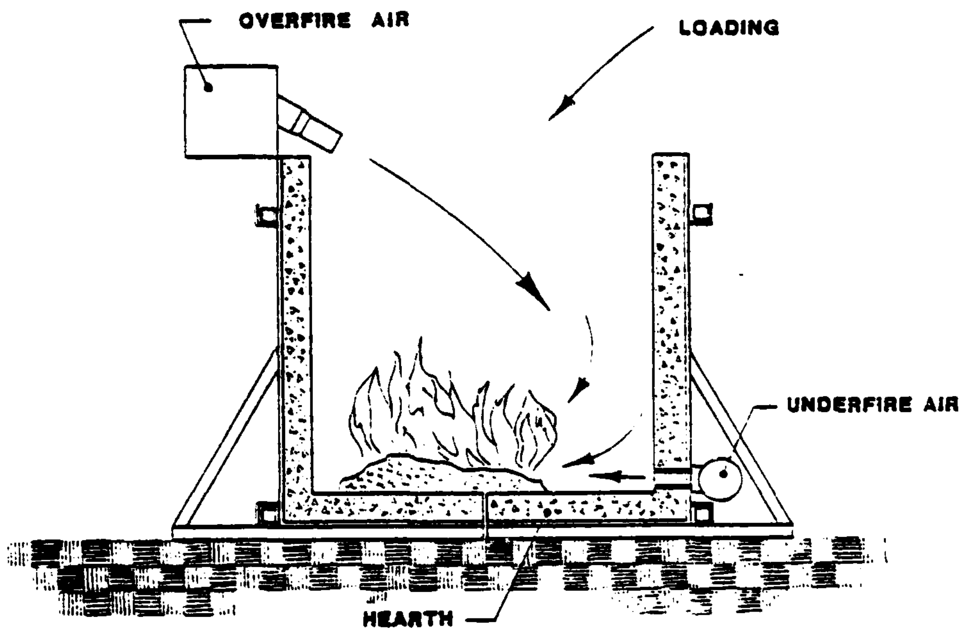
1.4 Description of Trecan Incinerator

The Trecan incinerator (figure 1) is designed to burn one ton per hour of oil-soaked debris resulting from the cleanup of an oil spill. The incinerator sections and auxiliary components can be transported to and assembled in remote or otherwise inaccessible areas using a medium lift helicopter. The combustion chamber is comprised of six "L"-shaped sections forming the sides and floor and four "I"-shaped end sections. Eight lengths of square tubing fit into troughs at the bottom and top of the side and end walls tying the ten sections together to form a chamber ten feet long, five feet wide, and five feet deep.

Combustion air supplied by a centrifugal fan is directed through a bank of nozzles at the top edge of the rectangular chamber and a small percentage through underfire nozzles penetrating the wall near the hearth. The blower is belt-driven by a 29.5 brake horsepower air-cooled diesel engine which is the only user of energy during incineration since combustion within the chamber is self-perpetuating.

The Trecan incinerator was designed to meet the following specifications:

Waste to be Incinerated:	Oil-soaked organic matter
Incineration Rate:	1 ton/hour at 7000 BTU/lb heating value
Loading Procedure:	Manual or front-end loader
Clean-out Procedure:	Manual
Performance:	Smoke density of No. 1 Ringleman or less
Maximum Weight per Section:	2000 pounds



CROSS SECTION OF TRECAN INCINERATOR

FIGURE 2

2.0 TEST DESCRIPTIONS AND RESULTS

2.1 T&E Subseries 1: Combustion Air Distribution

Objectives:

a. To determine air flow rates and patterns in combustion chamber.
b. To determine to what extent, if any, the thermocouple array which is to be placed inside the combustion chamber will affect air flow patterns.
c. To determine volumetric flow rates for the purposes of later positioning instruments to monitor gaseous and particulate emissions.
d. To determine whether the placing of a grate above the combustion chamber hearth has any effect on air flow patterns.
e. To determine what effect debris size has on air flow patterns.

Scope of Test and Results:

The incinerator was assembled without the two "I" sections of one end in place (figure 2). Over this opening a clear plexiglass sheet was clamped into place. Styrene plastic packing beads were then fed through the intake of the blower supplying combustion air to the chamber.

The test provided the opportunity to view the air circulation within the combustion chamber as it would occur during incineration. It was observed that once a styrene bead exited a nozzle, it would trace a circular path within the height and width of the chamber before being ejected to the atmosphere by moving upward along the back wall and between the nozzles of the overfire air duct. Estimated retention time of the styrene beads within the combustion chamber is less than one second.

In an attempt to increase retention time, the overfire air duct was moved back away from the chamber by extending the mounting studs. Although the air nozzle termini were now in a plane with the back wall of the incinerator, the air was directed to a point lower on the forward wall than previously. This arrangement did not induce rotational air flow.

Grating supported by firebrick six inches above the hearth did not disrupt the circular flow within the combustion chamber. It was also observed that debris resting directly on the incinerator hearth had little effect on the air movement within the chamber.

2.2 T&E Subseries 2: Maximum Disposal Rate

Objective:

To determine the maximum rate at which the Trecan incinerator is able to dispose of oil-soaked debris.

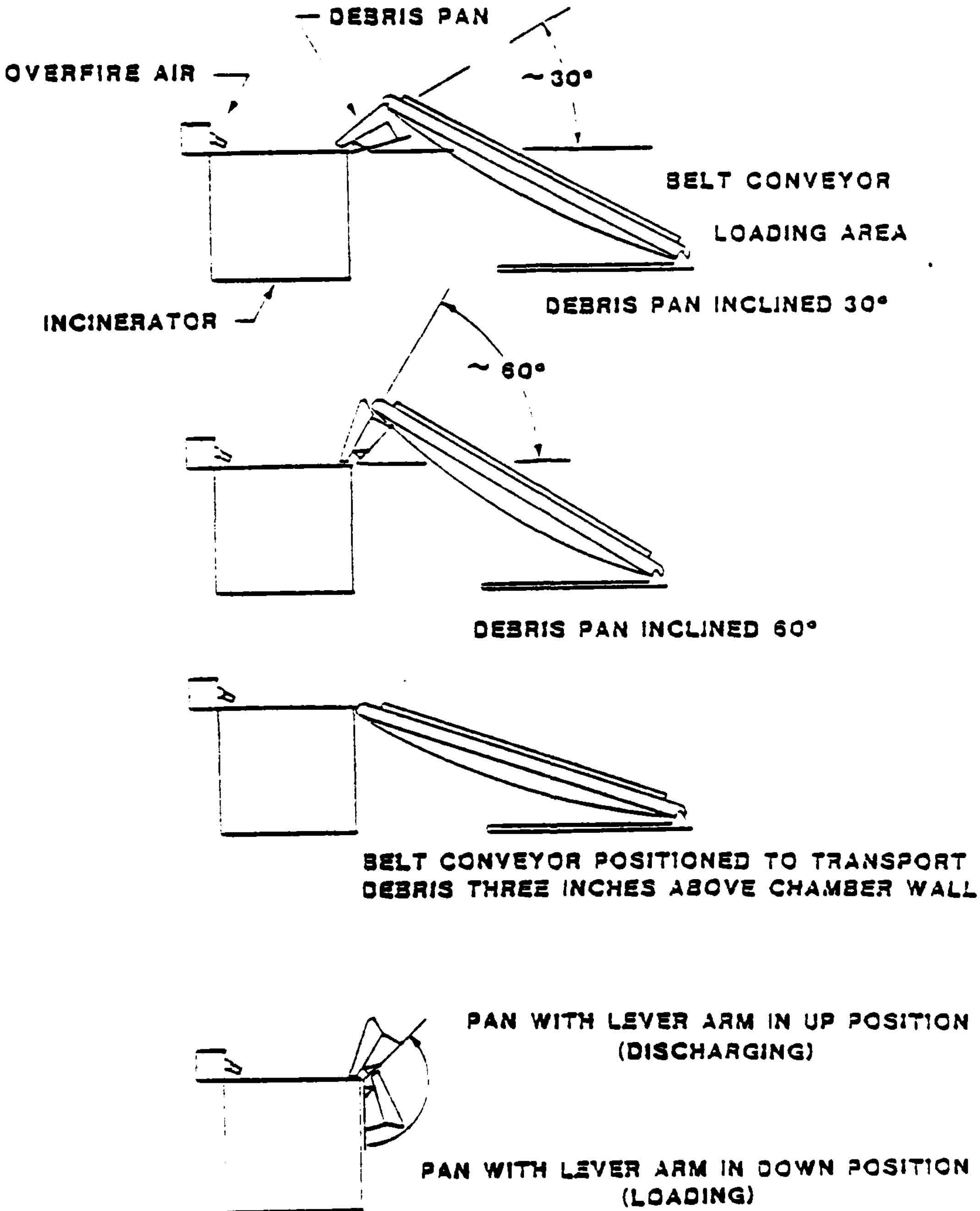


FIGURE 3

Equipment Configurations Tried in Loading the Incinerator

Scope of Test and Results:

Before beginning any testing, a method of loading the incinerator had to be devised so that personnel would be free to complete other tasks necessary for the test and evaluation series. A 16-foot continuous belt conveyor was used to move debris from the ground level to a height which would facilitate fast and safe loading. This method of loading debris could be used in the actual deployment of the incinerator. Power required to drive the conveyor could be obtained from the diesel engines 12V DC electrical system or mechanically driven by employing a flex drive. Figure 3 depicts the various equipment configurations tried in loading the incinerator.

The loading chute consisted of a strut-supported sheet metal debris pan with an open side. The pan's struts are fixed to a lever arm. With the lever in the down position, the pan is ready to receive debris. Manual lifting of this lever causes the loading chute's contents to slide into the combustion chamber. Because little mechanical advantage is realized from such an arrangement and because of the intense heat fluxes in the vicinity of the loading chute, its use as the primary means of charging the incinerator was abandoned in favor of the continuous belt conveyor.

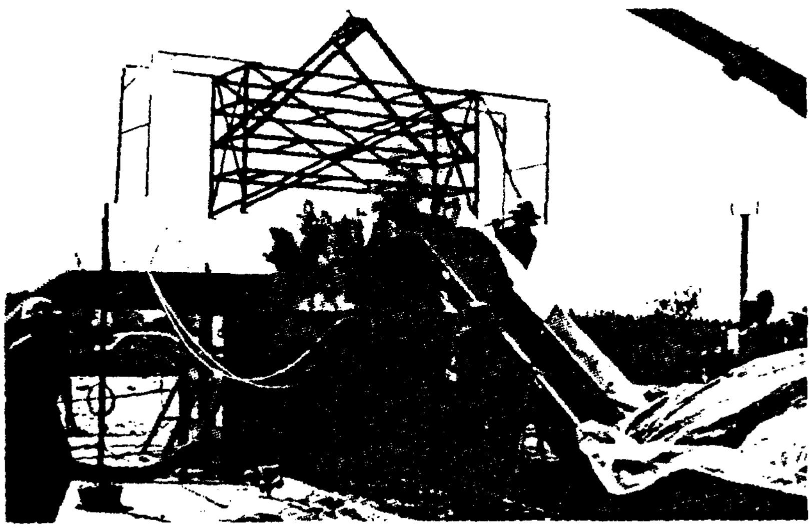


FIGURE 4

Loose debris being loaded onto continuous belt conveyor.
Note the man pushing debris down the loading chute with a pitchfork.

Although the conveyor solved the problem of having to manually raise the debris over the six foot-one half inch chamber wall, it was not without its problems. The conveyor was arranged such that the debris transported to the top would free-fall onto the loading chute sloped 30 degrees from the horizontal. This slope was found insufficient to allow debris to freely fall into the incinerator (figure 4). Increasing the slope of the loading chute to 60 degrees did not improve this situation; debris now tended to roll back down the conveyor belt before it could be discharged because of the conveyor's increased pitch. In both instances, the debris, if not immediately ejected from the loading chute, would ignite. A suitable arrangement for the test was

FIGURE 5

Conveyor belt positioned such that bundled or packaged debris is transported slightly above chamber wall.

made by positioning the conveyor so that the debris would be transported to a point three inches above the chamber wall thus permitting the debris to free-fall over the wall into the incinerator's combustion chamber without using the loading chute (figure 5). This scheme also shielded the belt, roller, and bearings from the radiant heat. Only debris which has been packaged, bundled, or baled can be loaded into the incinerator in this fashion.

To determine the maximum rate at which the Trecan incinerator was able to dispose of debris, the incinerator was charged with bales of straw fully saturated with No. 6 fuel oil. Each oil saturated bale contained 85 pounds of straw and 20 pounds of No. 6 fuel oil. Successive increases in the charge rate by ten pounds per minute as called for by the test plan was not carried out because small increases would not have a discernable effect on conditions observed from the previous charge rate.

The incinerator was charged first at a rate of 500 pounds per hour (one 105-pound bale every 12 minutes, 36 seconds). At this rate, the visual emissions (see appendix A for standard test method for relative density of black smoke) did not exceed one Ringlemann except during the recharging of the incinerator which caused particulates to be released which otherwise would have been contained within the combustion chamber. Loading of the incinerator manually at this charge rate could have been accomplished with some degree of safety. The total heat flux in the vicinity of the loading chute was below 0.11 $BTU/ft^2/sec$. Flame heights were less than the very top edge of the chamber walls.

Charging the incinerator with an oil-saturated bale every 6 minutes 18 seconds (1000 pounds per hour) produced emissions which were occasionally greater than one Ringlemann. Any charge rate greater than 1000 pounds per hour produced emissions which were consistently above one Ringlemann. Flames began to break through the air curtain. The thick ceramic chamber walls which provided a thermal barrier at a charge rate of 500 pounds per hour were not of sufficient height to permit personnel to work in the immediate area for any extended length of time at charge rates equal to or greater than 1000 pounds per hour.

At charge rates of 1500 and 2000 pounds per hour (figure 6), the density of the smoke issuing from the combustion chamber consistently exceeded two Ringlemann (40% opacity) and occasionally smoke density was as great as four Ringlemann (80% opacity). Heat fluxes typically fell in the 0.1-0.4 BTU per square foot per second range making it uncomfortable to be within 15 feet of the incinerator. Manual loading using the loading chute would be difficult at best because of the intense radiant heat. As the flames extended beyond the air curtain, it carried with it glowing embers of uncombusted straw. These embers were small enough to pass through the mesh of the screen cover. The possibility of glowing embers igniting dry ground cover or being carried over and onto the men loading the incinerator is a hazard which must not be overlooked when operating the Trecan incinerator.

FIGURE 6

Incinerator charged at a rate of 2000 pounds per hour of straw saturated with No. 6 oil

Sound level measurements were made at 40 locations in the work areas adjacent to the incinerator. A polar plot containing contour lines of equal sound levels is given in figure 7. The sound levels encountered presented no problems to those working in the loading area.

2.3 T&E Subseries 3: Reduction of Smoke Generation

Objective:

To determine if the amount of excess combustion air in any way influences the quantity of smoke generated.

Scope of Test and Results:

The incinerator was charged at 1000 pounds per hour while combustion air was supplied at one-fourth and three-fourths the maximum blower output. It was observed that an increase in the amount of combustion air supplied to the combustion chamber resulted in a reduction of the amount of smoke generated for a given quantity of debris incinerated. The grating was not used to conduct the second part of the test as outlined in the test plan because it would not have survived the high temperatures.

2.4 T&E Subseries 4: Oil Water Emulsions

Objective:

To determine the incinerator's ability to dispose of debris containing various oil water emulsions.

Scope of Test and Results:

It was observed in T&E Subseries 3 that debris being incinerated will produce smaller quantities of smoke if a greater amount of combustion air is supplied to the chamber. All subsequent tests were conducted with the blower output being at a maximum.

Straw bales saturated with oil water emulsions having a water content of 25 to 90 percent were incinerated at rates ranging from 1000 to 2000 pounds per hour. The aggregate weight of each bale varied from 105 pounds for a bale saturated with 25% water-75% oil emulsion down to a weight of 95 pounds for bales containing a 90% water-10% oil composition. The apparent decrease in aggregate bale weight with increasing water content of the emulsion was due to the emulsion's inability to adhere to the straw fibers.

The consequence of adding water to No. 6 fuel oil was to lower chamber temperatures (see appendix B for temperature histories of various emulsions) and to reduce flow rates of the combustion gases. This allowed for more complete combustion of the oil resulting in a general lowering of emissions and particulate size. Increasing the water content of an emulsion above 25% did not effect a detectable reduction in the amount of visual emissions for a given charge rate.

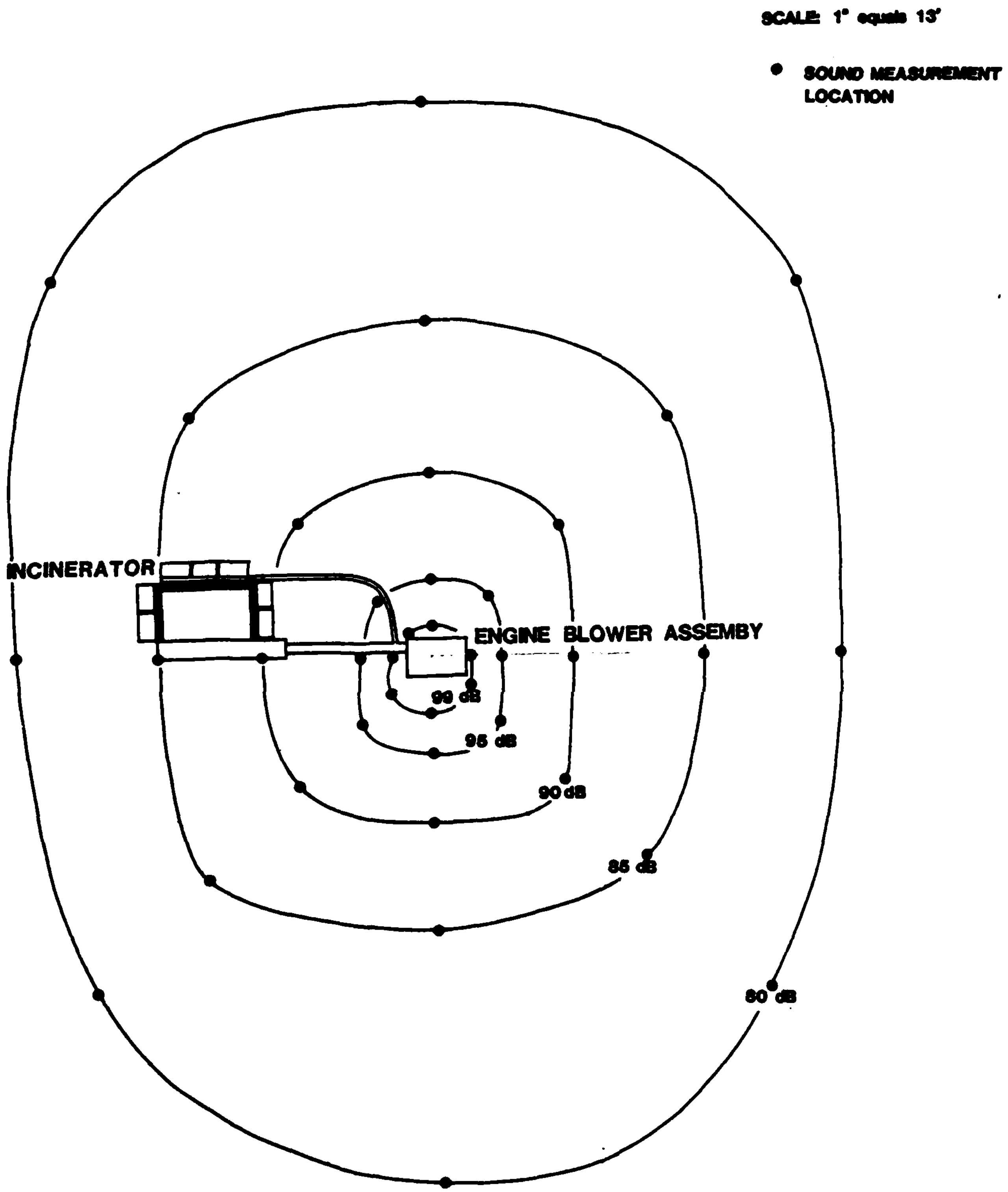


FIGURE 7

Sound Level Measurements and Locations

2.5 T&E Subseries 5: SO_x, NO_x, and Particulate Emissions

Objective:

1. To determine SO_x, NO_x, and particulate concentrations generated during incineration of typical harbor and beach debris using EPA test methods and procedures.

2. While originally intending to determine the dispersion of gaseous and particulate matter in the surrounding environment, this analysis was not done because it was not considered to be of practical value. The basis for that decision was: first, the emission source is small and is not in a permanent location, and second, the variability of terrain and the influence it has on dispersion makes the results site specific.

Scope of Test and Results:

It was determined from Test 2 that the incinerator charged with bales saturated with No. 6 oil at a rate of 1000 pounds per hour generated emissions which were occasionally greater than one Ringlemann. The amount of radiant heat was such that manual loading could be accomplished but not without some degree of discomfort to operating personnel. The addition of water to the No. 6 fuel oil in Test 4 coupled with combustion air being supplied at the maximum rate considerably reduced the amount of visual emissions. The combined results of these previous tests were to minimize the amounts of visual emissions. This laid the groundwork necessary to conduct gas and particulate concentration measurements. This test quantified NO_x and SO_x concentrations, hydrocarbon constituents, particulate sizes, and particulate mass flux for straw debris saturated with an emulsion containing 50% water and for debris saturated only with No. 6 fuel oil. The data was collected and analyzed by Mobil Research and Development Corporation, the results of which are included in appendix C.

2.6 T&E Subseries 6: Air Transportability

Objective:

To determine Coast Guard aircraft capabilities in transporting the Trecan Limited incinerator.

Scope of Test and Results:

Helicopter transport and assembly of the Trecan incinerator took place on a large concrete surface area at Brookley Industrial Park, Mobile, Alabama. Weather conditions during the test included a sunny cloudless day, becalmed winds, a relative humidity of 78% and air temperatures between 98^{o}-103^{o}F.

Four incinerator sections and the overfire air plenum were hoisted, transported, and assembled with the HH3F helicopter. The capability of the HH3F lifting and moving a 2000-pound object such as an incinerator component was documented in a letter from Commanding Officer, Coast Guard Aviation Training Center dated 18 March 1980. It was felt that the HH3F would be well suited for the mission subject to limitations given in appendix D. This enclosure to the Aviation Training Center's letter contains performance data that relate to fuel required and fuel available for given flight conditions.

The hoisting of the incinerator was a time-consuming task. The lifting device is first attached to the incinerator section which is to be lifted. This device ensures that the base of the section is horizontal thus enabling it to be set exactly in its assembled position. A pendant is then fastened to the lifting device. Once these two pieces of hardware are readied, lifting of the section by helicopter can commence. The helicopter must hover low enough to permit use of a dead man's stick to discharge the static electricity before manual coupling of the pendant to the aircraft frame can be effected. Positioning of the helicopter was guided by hand signals given by an air crew member on the ground. Once off the ground, the incinerator sections were positioned 50 yards from the pickup point for assembly.

Several problems were encountered. The most apparent of these was the incincerator end sections' high center of gravity which resulted in their being toppled by the helicopter's rotor wash. This resulted in some of the refractory being broken off near the edges or cracking across the incinerator wall face. However, the incinerator still could have been assembled and operated. Extreme care had to be exercised when positioning each section in its final assembled position. There were no fabricated handholds. By holding the steel frame supporting the refractory material, one risks having their feet beneath the suspended moving load as it was being positioned. The assembly crew of three people had a hard flat working surface to position the incinerator sections on.

FIGURE 8

Transporting the overfire air plenum.

This type of situation would not likely be encountered at the scene of an actual oil spill. The crew was of the opinion that they were never fully in control of the load as they attempted to position the incinerator sections. While the incinerator sections were very stable when transported, the overfire air plenum teetered (figure 8) when attached to the center lifting eye. Repositioning of the lifting eye at the end of the plenum would resolve this problem.

If assembly of the incinerator were to take place at a remote location, site selection is critical. Because the helicopter hovered as close as 12 feet above the ground (figure 9), the rotor wash is likely to carry dirt and debris with it. The helicopter's rotor wash will always be a problem in such a situation unless longer pendants are used permitting the helicopter to work at a higher attitude. The lifting device and pendant could be recovered by using the powered hoist thereby allowing the helicopter to maintain this higher attitude during the entire assembly evolution.

FIGURE 9

Helicopter hovering for section pick-up. Ground signalman is to the left of center.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Durability of Incinerator Sections

The incinerator sections were made of materials which were able to withstand the extreme temperature ranges, rapid temperature changes, and mechanical abuse that occurred during testing. The long tractor-trailer trip from Mississauga, Ontario, to Mobile, Alabama, resulted in cracks penetrating through the width of the wall of all incinerator section (figure 10). The refractory's structural integrity was maintained by heavy steel support framing, refractory anchors, "Niles" expanded metal structural grating, and the addition of stainless steel needles to the refractory before casting. The fact that the incinerator end sections were toppled from the rotor wash, yet remained intact, is a testimonial to this integrity.

FIGURE 10

Two of the incinerator's end sections. The cracks shown here were typical of those found on all other incinerator sections.

3.2 Durability of Incinerator Components

The fabricated steel components were all found to be adequate for their intended purpose. Moderate surface warpage to the overfire air plenum caused slight reorientation of the nozzles. This warpage, however, was not severe enough to affect incinerator performance. Operators should ensure that the pulleys of the diesel engine and blower are coplanar. Non-alignment during the test resulted in excessive belt wear and premature failure.

3.3 Performance of the Incinerator

The maximum amount of oily debris which can be fed into the combustion chamber safely was found to be no greater than 1000 pounds per hour. This finding coincides with other tests and evaluations of the Trecan incinerator conducted in Canada. The incinerator fired at a rate greater than this produced emissions which consistently exceeded one Ringlemann (20% opacity). If greater disposal rates are desired, a mechanical delivery system other than the loading chute should be used to deliver the debris to the combustion chamber. It should be designed to eliminate personnel being exposed to the intense radiant heat developed at feed rates at or greater than 1000 pounds per hour.

The addition of water to the oil markedly reduced the visual emissions. If the incinerator is operated in an area where unsightly emissions would be of concern, oiled debris containing 25% to 75% water should be incinerated.

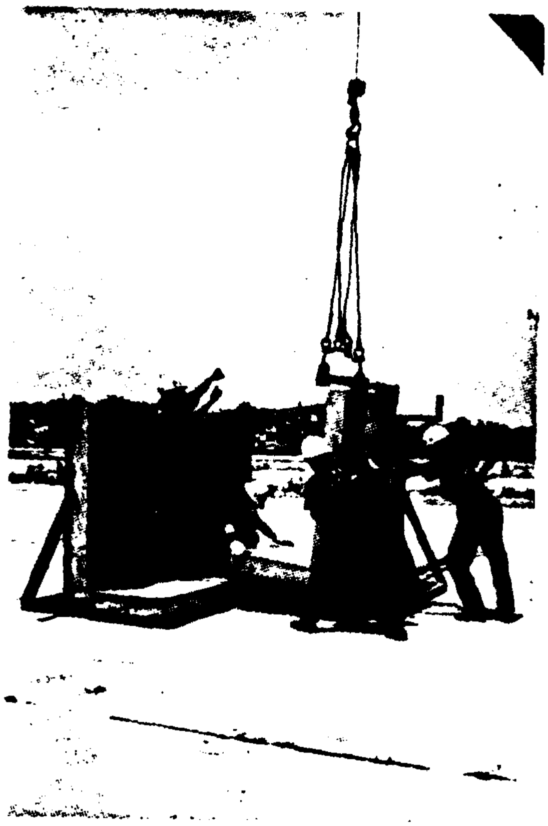
3.4 Suitability of Incinerator to Air Transport

The HH3F is the only helicopter possessed by the Coast Guard which could be used to hoist, transport, and assemble the Trecan incinerator in an area which is inaccessible by land vehicles. As indicated by the helicopter's performance data, the farthest that such an operation could be accomplished under ideal conditions without refueling between pickup and assembly points by the aircraft is 60 nautical miles per round trip. Thirteen round trips would be required to assemble the incinerator at this distance.

The massiveness of the incinerator sections caused considerable difficulty to the ground crew during the positioning and assembly evolution. A level surface is an absolute necessity for the successful mating of these sections. A reduction in the weight of these components would greatly enhance the practicality of transporting the incinerator sections and components.

3.5 Safety of Operation

The present loading arrangement allows safe loading of packaged or bundled debris at charge rates up to 1000 pounds per hour. Loose debris is difficult to deposit in the combustion chamber particularly when saturated with oil. Eliminating the need to manually lift the debris over the six-foot incinerator wall would improve the operation's safety posture while reducing the manual labor involved.



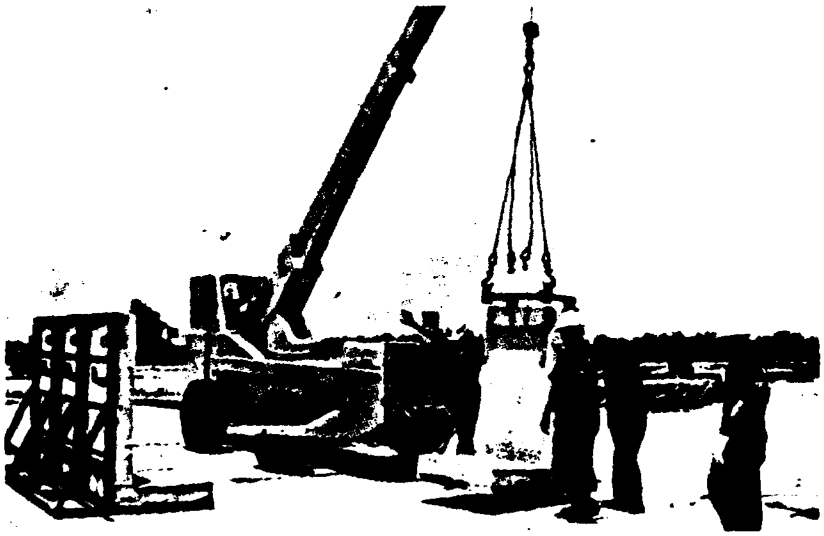


FIGURE 11

Incinerator sections being assembled with a crane car.

Siting of the incinerator is a consideration which should not be given careful consideration. It is important to locate the incinerator downwind from the loading area so that hot embers will not be carried over and onto the personnel operating the incinerator. Although the overhead screen which serves to prevent flaming or glowing embers from escaping the combustion chamber was not used in the test and evaluation, it would not have been effective in containing the size of burning debris being ejected from the incinerator during these tests.

3.6 Refractory Material

It would be possible to reduce the amount of refractory provided that the debris is of small bits and pieces thereby eliminating the damage caused by heavy freefalling debris. This might be accomplished by processing all debris through a shredder and then feeding it into the combustion chamber by a worm screw conveyor. Reducing the refractory weight would enhance transportability, perhaps to a point where a HH52A or HH65A helicopter could be used.

3.7 Ease of Assembly

The geometrically simple shapes of the incinerator sections made assembly uncomplicated to a degree that it could have been accomplished without instructions. Each section can be conveniently moved and set into place using a crane car; however (figure 11), the safety of moving and assembling the Trecan incinerator with the HH3F helicopter is very marginal.

3.8 Fabrication of the Incinerator

The Research and Development Center contracted Trecan Limited to build the incinerator at a cost of approximately $40,000 in March of 1980. The incinerator was delivered in Mobile, Alabama, two months later. This was after a one-week delay in delivery of the finished product was experienced because of supplier delays of items necessary for incinerator fabrication. It is inconceivable that the concept of stocking the complete set of incinerator blueprints rather than the finished incinerator sections and components would result in an incinerator built and delivered for immediate use. The reasons that would preclude such a concept are that the construction of the incinerator would be far from material supplies and skilled labor.

APPENDIX A

Standard Test Method for Relative Density of Black Smoke

Standard Test Method for RELATIVE DENSITY OF BLACK SMOKE (RINGELMANN METHOD)[1]

This standard is issued under the fixed designation D 3211; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This method covers the determination of the relative density of black smoke.

1.2 The apparent darkness or opacity, or both, of a stack plume depends upon the following:

1.2.1 The concentration of particulate matter in the effluent.

1.2.2 The size of the particulate.

1.2.3 The depth of the plume being viewed.

1.2.4 Natural lighting conditions, such as the direction of the sun relative to the observer, and the amount of light.

1.2.5 The color of the particulates, and

1.2.6 The background conditions.

1.3 In the determination of visual emissions, the Ringelmann Smoke numbers are considered a special case for measuring shades of black or gray of fly ash arising from combustion processes.

2. Summary of Method

2.1 The Ringelmann Smoke Chart, indicating shades of gray (blend of black and white) by which the density of smoke rising from stacks may be compared, is used to determine the density of the black smoke. A qualified observer may use the Ringelmann Chart, or other aids to make this determination.

3. Significance

3.1 The Ringelmann Chart was originally intended as a guide for plant operators in adjusting furnaces to burn coal efficiently. Since the emission of soot is an inherently preventable act of pollution, it was then adopted by many jurisdictions as a basis of air pollution control regulations. Despite its subjective nature, it has been found useful in precisely this context. In addition, Ringelmann readings tend to correlate closely with adverse public reaction to the sight of a discharge of black smoke, and probably less well with the potential of that smoke to degrade visibility. Ringelmann readings are a subjective test, and may or may not be a direct measure of the quantity of emission.

4. Interferences

4.1 Errors or variations in Ringelmann reading may occur due to the following conditions:

4.1.1 Variations in the background against which the smoke is viewed.

4.1.2 Variations in the ambient light which illuminates the Ringelmann charts and which may be considerably different from the light in the area of the stack.

4.1.3 The optical focus of the observer's eyes when looking from the smoke to the charts or data sheets, or both, and

4.1.4 Changes in the type of fuel burned and variations in the fuel result in different smoke density emissions due to water vapor, particulate size, shape, and color.

5. Apparatus

5.1 Ringelmann Smoke Chart,[2] which employs a scheme whereby graduated shades of

[1] This method is under the jurisdiction of ASTM Committee D-22 on Methods of Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.06 on Source Sampling.

Current edition approved Feb. 23, 1979. Published April 1979. Originally published as D 3211 – 73 T. Last previous edition D 3211 – 73 T.

[2] Described in U. S. Department of Interior Bureau of Mines Information Circular 8333 issued May 1967.

gray, varying by five equal steps between white and black are employed to evaluate the density of smoke emissions.

5.1.1 Ringelmann Smoke Chart shall be produced by preparing a rectangular grid of carbon-black lines of definite width and spacing on a flat-white background of paper or cardboard having a reflectance equivalency of reagent grade magnesium oxide (MgO) powder or barium sulfate ($BaSO_4$) powder.

Cards 154.5 mm wide by 224.5 mm long shall be prepared as follows:

Card 0 All white, percent black 0.

Fig. 1 Card 1 Black lines 1 mm wide, 10 mm apart, leaving white spaces 9 mm square, with 6.75 mm white border, percent black 20.

Fig. 2 Card 2 Black lines 2.3 mm wide, 10 mm apart, leaving white spaces 7.7 mm square, with 6.1 mm white border, percent black 40.

Fig. 3 Card 3 Black lines 3.7 mm wide, 10 mm apart, leaving white spaces 6.3 mm square, with 5.4 mm white border, percent black 60.

Fig. 4 Card 4 Black lines 5.5 mm wide, 10 mm apart, leaving white spaces 4.5 mm square, with 4.5 mm white border, percent black 80.

Card 5 All black, percent black 100

5.2 *Micro-Ringelmann Smoke Chart*[3] (Fig. 5)—a direct facsimile reduction of the standard Ringelmann Smoke Chart employs the same scheme as the Ringelmann but the smaller scale permits easier handling.

5.3 *Smoke Scope*[4], which incorporates a viewing apparatus to compare the smoke being observed to a reference film. Light from an area adjacent to the smoke being observed is transmitted through the reference film onto a mirror, and then through a lens onto a second mirror. From this second mirror, the reference image can be compared with the smoke being observed. The reference film is located exactly at the focal distance of the virtual image; therefore the image can be compared to the smoke being observed without refocusing of the observer's eye.

6. Calibration and Standardization

6.1 *Qualification of Observer*—Any qualified observer must complete a smoke-reading course with a content approved by or conforming to the course presented by The Environmental Protection Agency (EPA).[5] Upon completion of the course, any qualified observer must be certified by the agency or a recognized organization giving the course. To pass the test for certification, an observer must be able to assign Ringelmann numbers (to the nearest 0.25 Ringelmann number) to 25 different smoke plumes, with an error not to exceed 15% on any one reading and an average error not to exceed 7.5% on all 25 readings. All qualified observers must pass this test every year in order to remain certified.

6.2 The smoke generator used to train the observers must have the capabilities to produce gray/black smoke from 0 to No. 4 Ringelmann. A calibrated smoke indicator or light transmission meter located in the source stack of the smoke generator shall be used for the actual determination of the related Ringelmann emission readings.

7. Procedure

7.1 *General:*

7.1.1 Glance at the stack every 15 to 30 s using the observer's own trained eyes or using the aid of a Ringelmann chart, micro-Ringelmann, or smoke scope. Record the data as stated in Section 8, using the recommended data forms. Ringelmann numbers correspond to the following densities of smoke:

Ringelmann Number	Percent Light Transmission through Smoke	Smoke Density, %
0	100	0
1	80	20
2	60	40
3	40	60
4	20	80
5	0	100

7.1.2 Record the Ringelmann number to the nearest ¼ fraction of a whole Ringelmann number that the observer is capable of reading. Record the conditions under which the reading is being taken. Under adverse conditions, such as noted in Section 4 or when the observer must deviate from the procedures listed, the observer shall use whole Ringelmann number readings.

7.1.3 In determination of the smoke emissions, readings should be taken over a relatively long period of time, for example, 1 h, or if the process is a batch-type operation, then readings

[3] Published by McGraw-Hill Publishing Co.

[4] Manufactured by the Mine Safety Appliances Co. or the equivalent thereof.

[5] Smoke reading courses are offered by EPA Regions I, II, IV, and VII, as well as by most states, and by a few major air pollution control districts.

should be made over at least one complete cycle.

7.2 *Use of The Ringelmann Smoke Chart:*

7.2.1 Support the chart on a level with the observer's eye, in line with the smoke plume being observed, and at such a distance (about 50 ft from the observer) that the lines on the chart merge into shades of gray. Glance from the smoke plume to the chart, and determine the Ringelmann number that most nearly corresponds with the shade of the smoke being observed.

7.2.2 Observe the smoke at approximately right angles to the direction of plume travel, with the sun behind the observer as much as possible. Observe the smoke at the point of exit from the stack, except for detached plumes (which shall be observed at the point of greatest density) and plumes containing steam (which shall be observed just beyond the point of steam dissipation).

7.2.3 Observe the smoke against a contrasting background (usually the blue sky), and with enough light present so that the plume can be adequately seen. Where air pollution control regulations permit nighttime observations, use back lighting. The observer must be trained and certified for nighttime readings before reporting such readings.

7.2.4 Stand at least two stack heights away from the stack being observed, and not more than 2500 ft (762 m) from the stack.

7.3 *Use of the Micro-Ringelmann Smoke Chart:*

7.3.1 Support the chart on a level with the observer's eye, in line with the smoke plume being observed, at approximately an arm's length from the observer or at a distance that the lines on the chart merge into shades of gray. View the smoke plume through the slot in the middle of the chart, and determine the Ringelmann number that most nearly corresponds with the shade of smoke being observed.

7.3.2 See 7.2.2 to 7.2.4.

7.4 *Use of the Smoke Scope:*

7.4.1 View the plume through the instrument, aiming it so that smoke fills the field of vision through the aperture. Compare the reference images to the smoke plume being observed, and determine the Ringelmann number that most nearly corresponds with the shade of smoke being observed.

7.4.2 See 7.2.2 to 7.2.4.

8. Calculation and Report

8.1 *Determination of Average Smoke Density*—Observe the smoke density, using the Ringelmann Smoke Chart, the Micro-Ringelmann Smoke Chart, or the smoke scope, at constant intervals of 15 or 30 s. At the end of the observation period, divide the sum of the Ringelmann numbers by the total number of observations made. The results shall be the average smoke density, expressed as a Ringelmann number.

8.2 *Percentage Smoke Density*—Any smoke density expressed as a Ringelmann number can be converted to a percentage smoke density by multiplying the Ringelmann number by 20. Thus, a Ringelmann Number 1 would equal a 20% density, and a Ringelmann Number 5 (black smoke) would equal a 100% density.

8.3 *Suggested Data Form*—A convenient form for recording and computing the average percentage of smoke density, as well as the average Ringelmann, over a time period of 1 h is shown in Fig. 6.

FIGS. 1–4 Ringelmann's Scale for Grading the Density of Smoke[4]

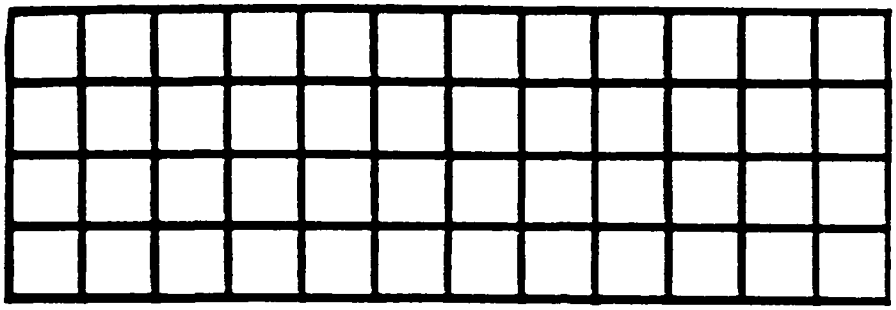


FIG. 1 Equivalent to 20 Percent Black.

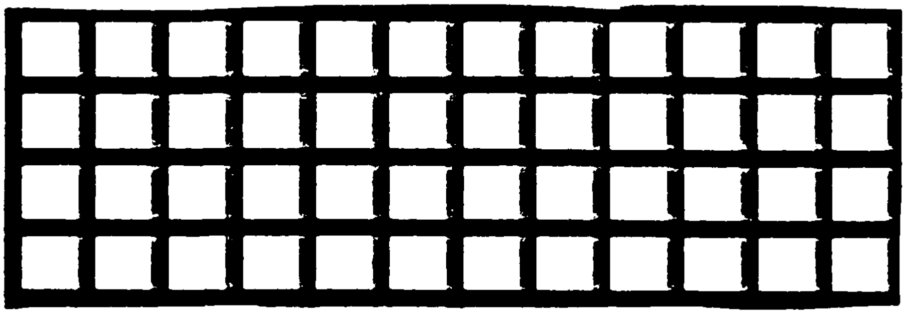


FIG. 2 Equivalent to 40 Percent Black.

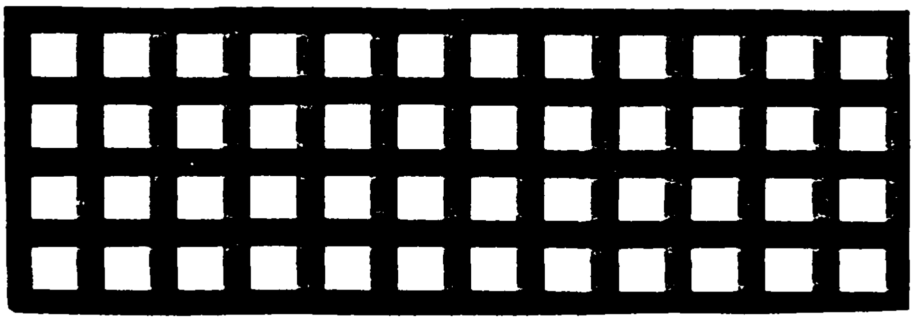


FIG. 3 Equivalent to 60 Percent Black.

[4] A print for the Ringelmann's Scale for Grading the Density of Smoke is available at a nominal charge from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. 19103. Request adjunct No. 12-432110-00.

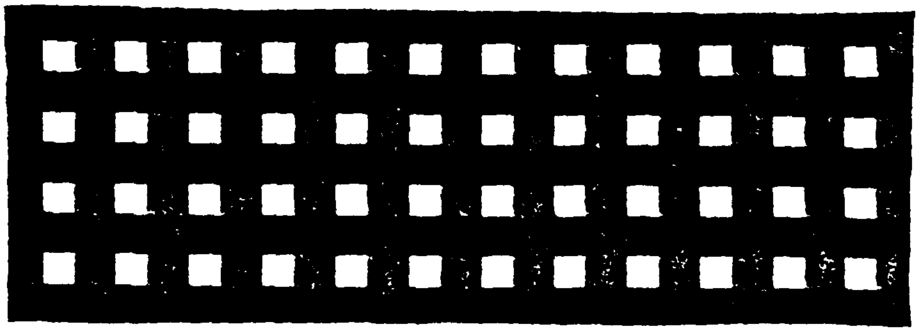


FIG. 4 Equivalent to 80 Percent Black.

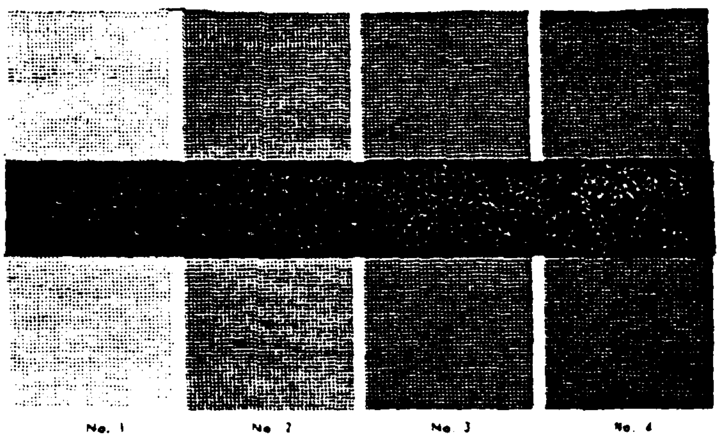


FIG. 5 Micro-Ringelmann Smoke Chart.

SMOKE OBSERVATION FORM

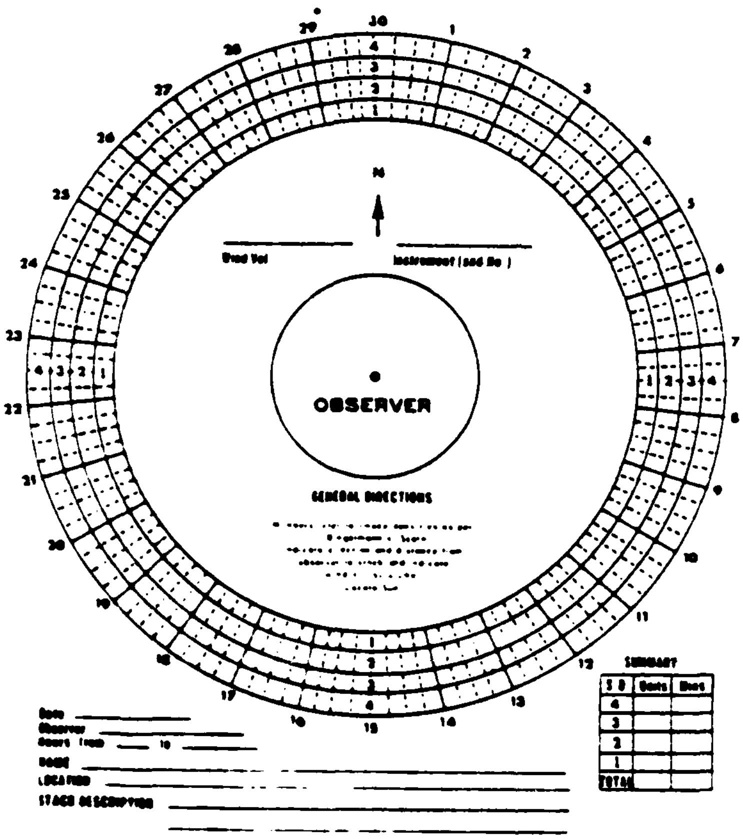


FIG. 6 Smoke Observation Form

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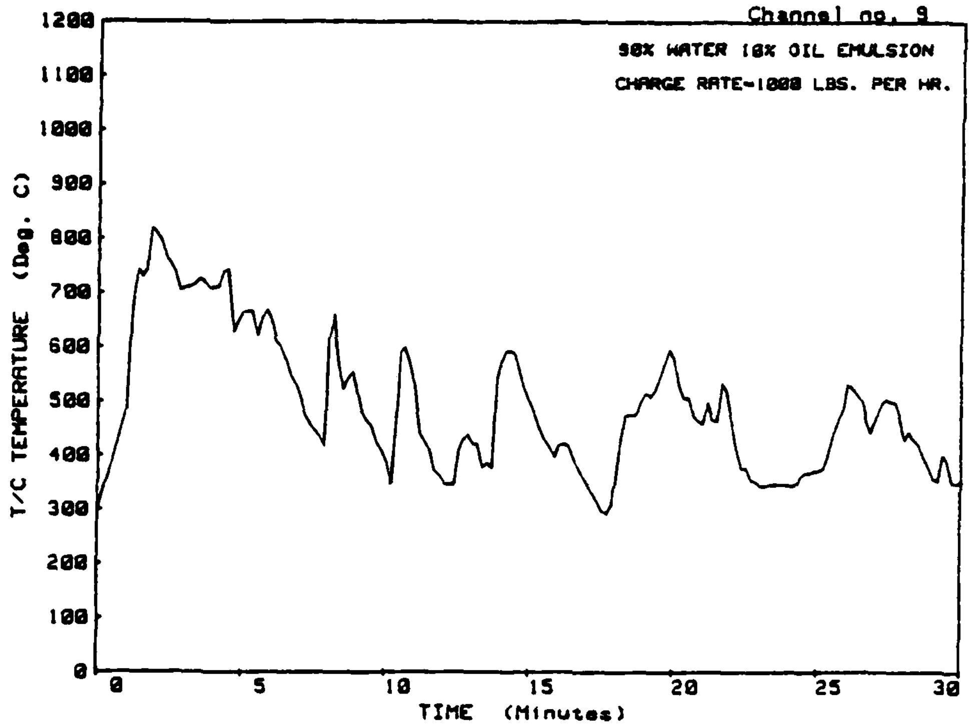
This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

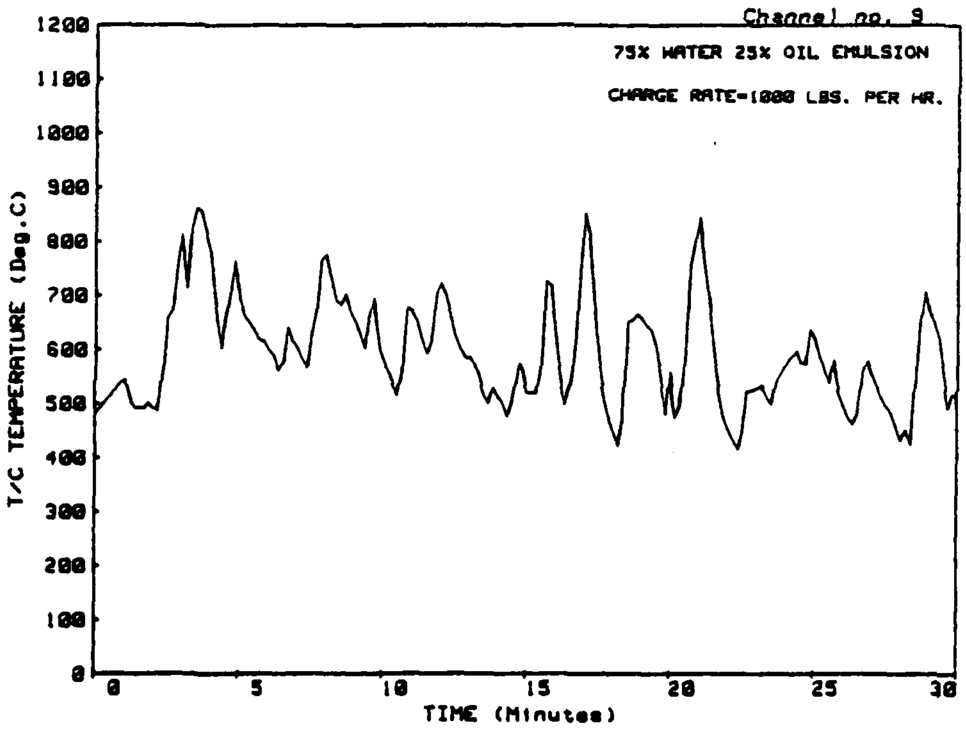
APPENDIX B

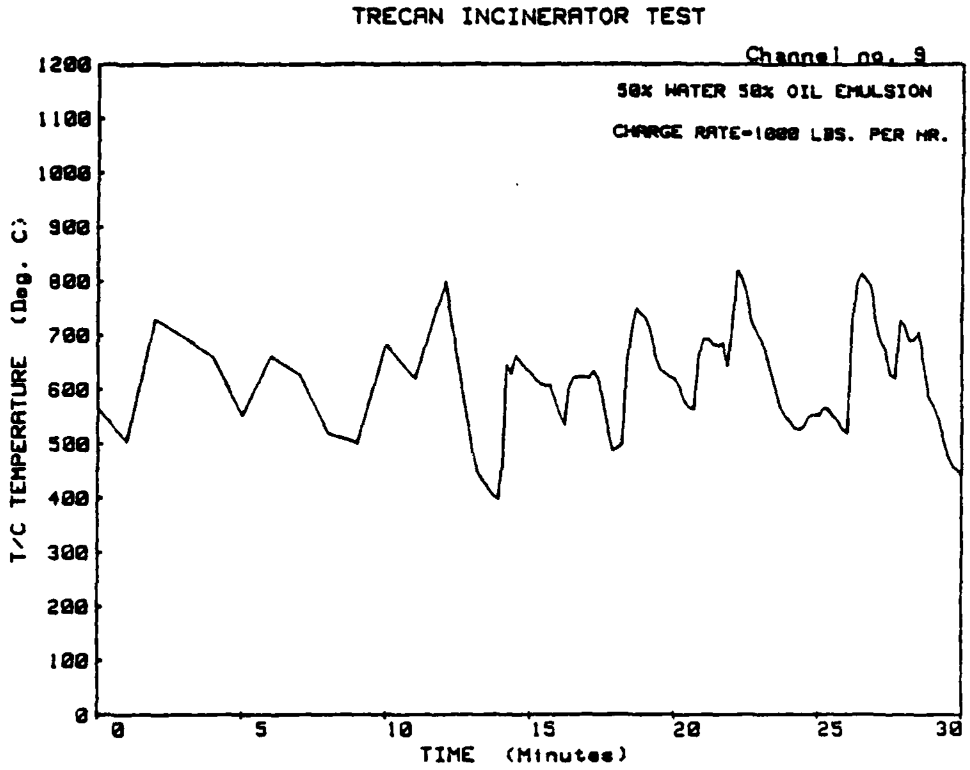
Temperature and Heat Flux Histories

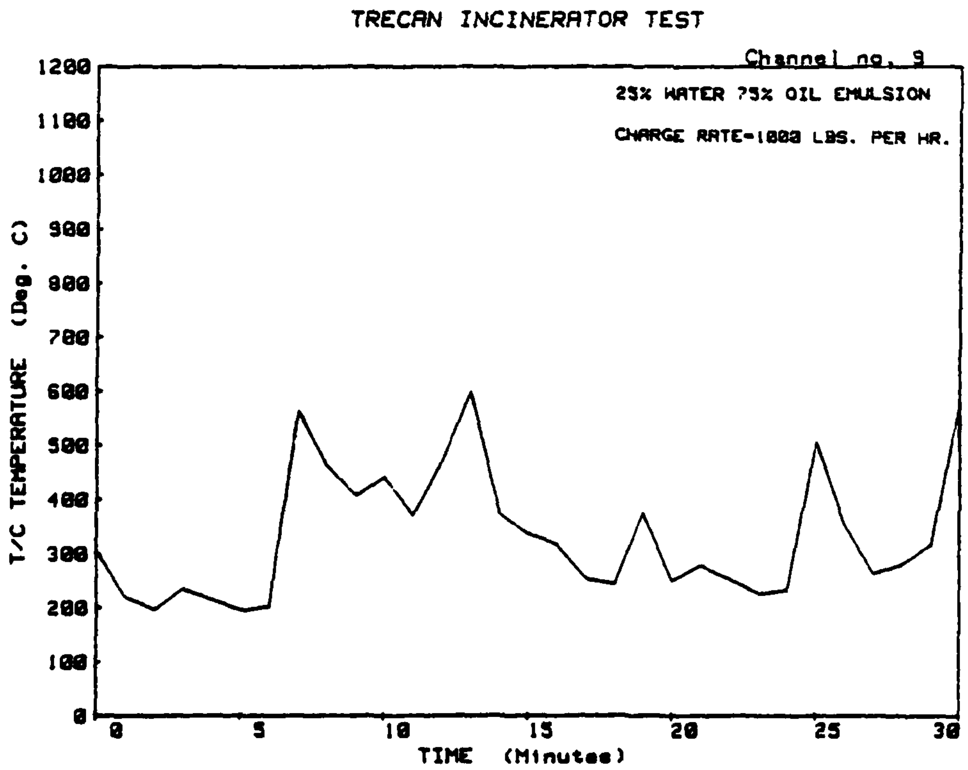
TRECAN INCINERATOR TEST

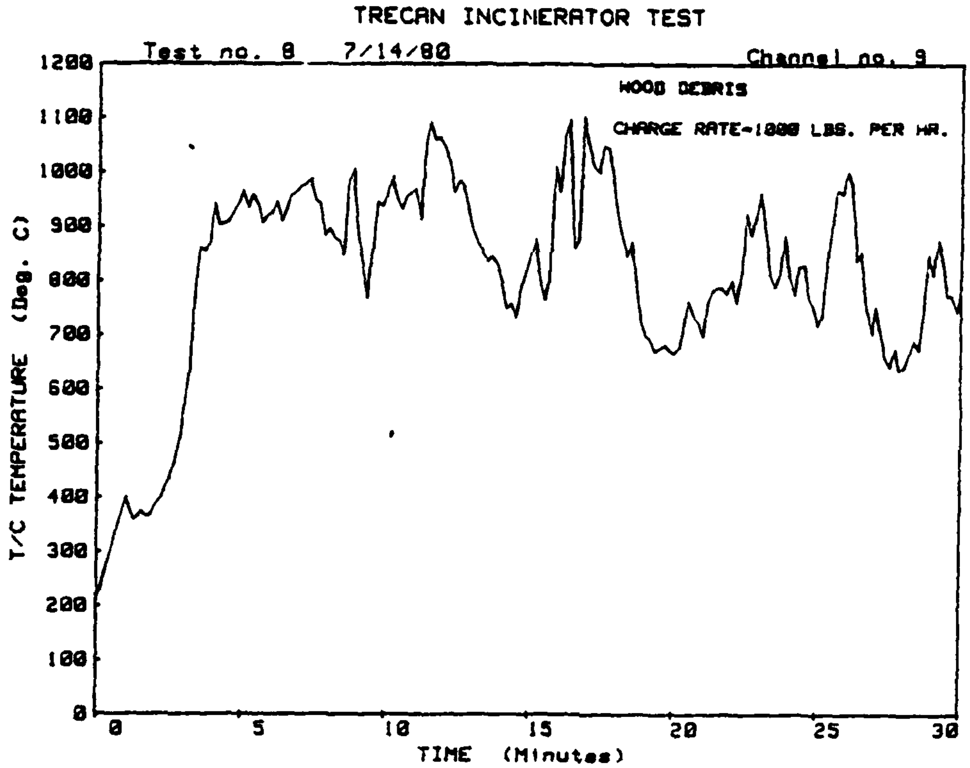


TRECAN INCINERATOR TEST

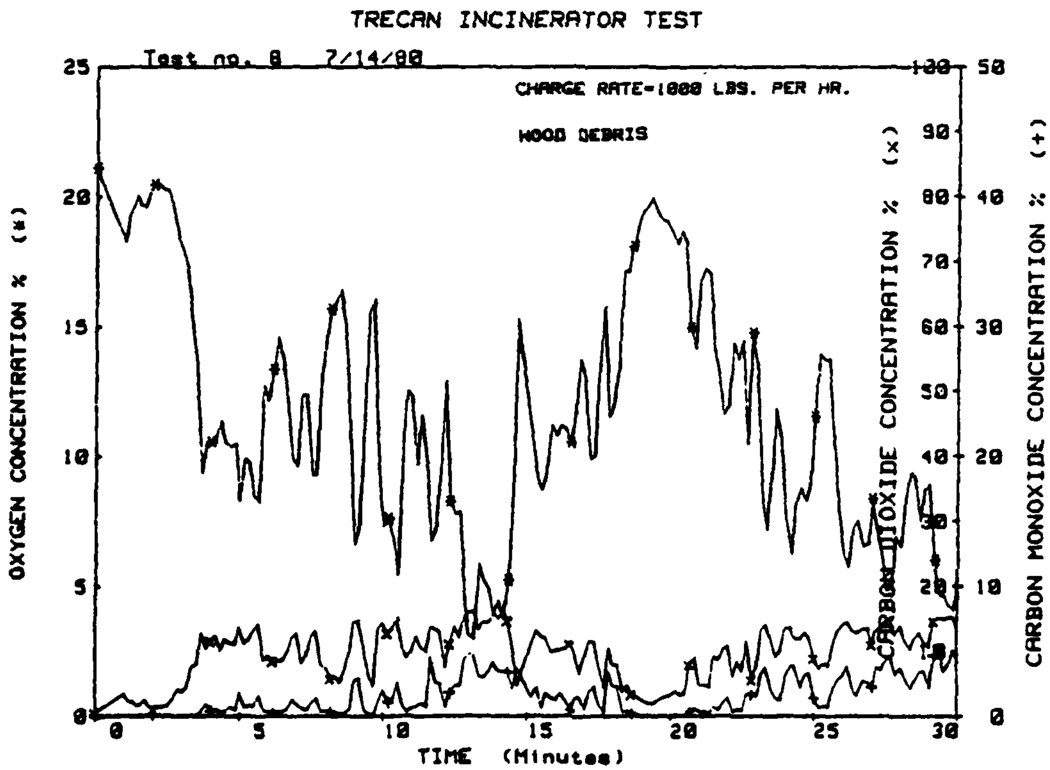



TRECAN INCINERATOR TEST
Channel no. 9
50% WATER 50% OIL EMULSION
CHARGE RATE=1000 LBS. PER HR.
T/C TEMPERATURE (Deg. C)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
TIME (Minutes)

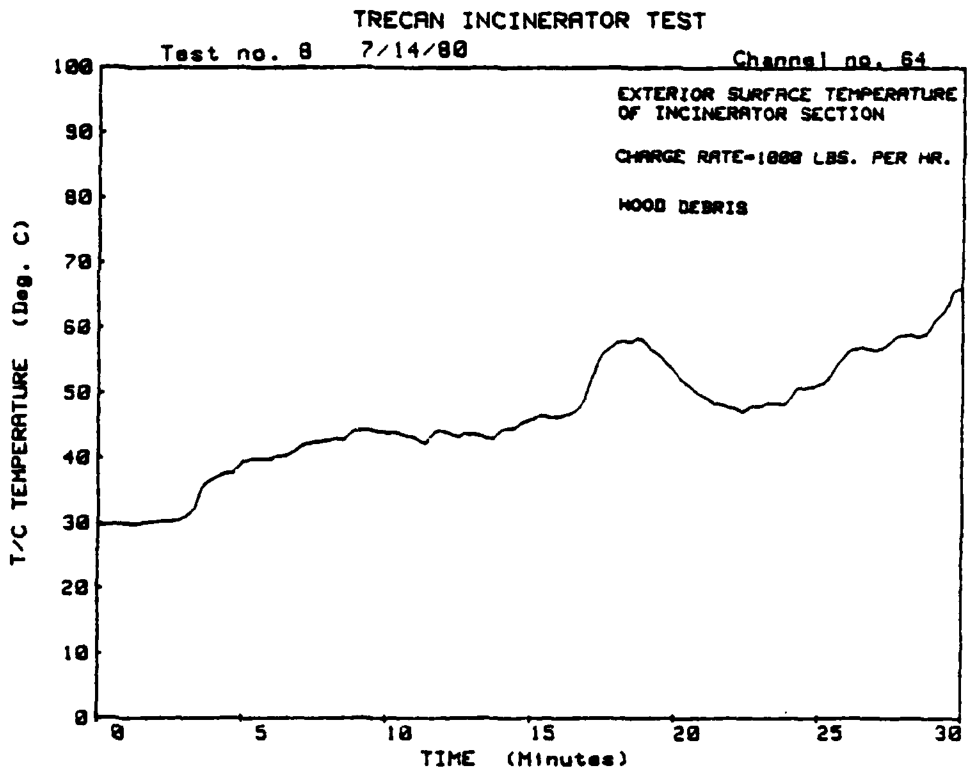

TRECAN INCINERATOR TEST
Channel no. 9
25% WATER 75% OIL EMULSION
CHARGE RATE=1000 LBS. PER HR.
T/C TEMPERATURE (Deg. C)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
TIME (Minutes)



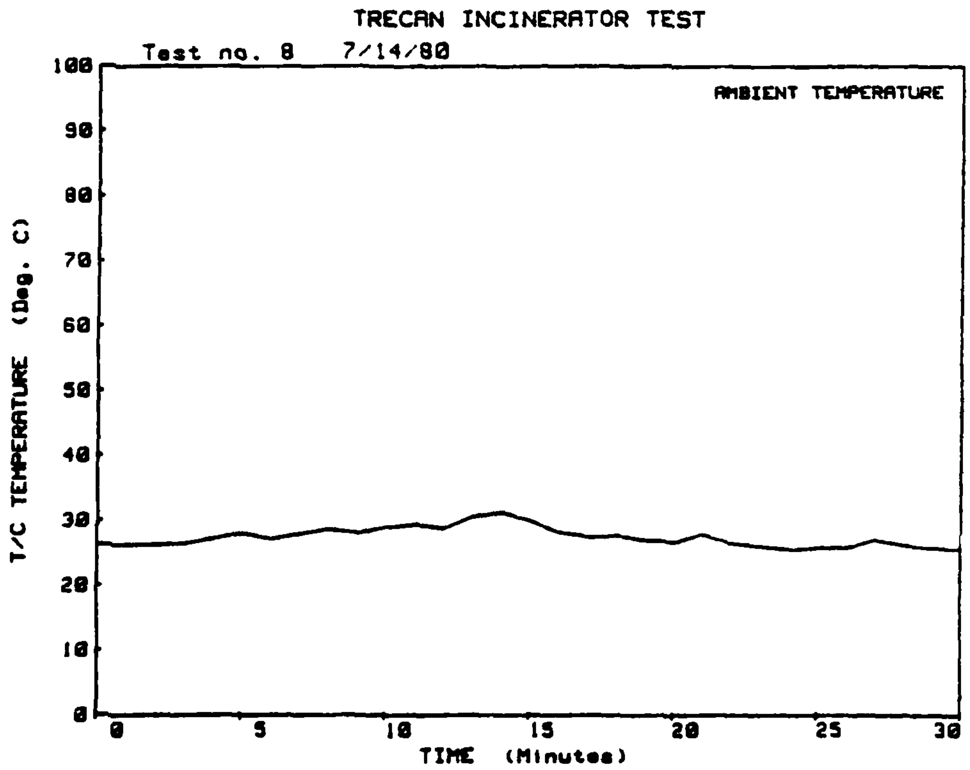
TRECAN INCINERATOR TEST
Test no. 8 7/14/80
Channel no. 9
WOOD DEBRIS
CHARGE RATE=1000 LBS. PER HR.
T/C TEMPERATURE (Deg. C)
TIME (Minutes)



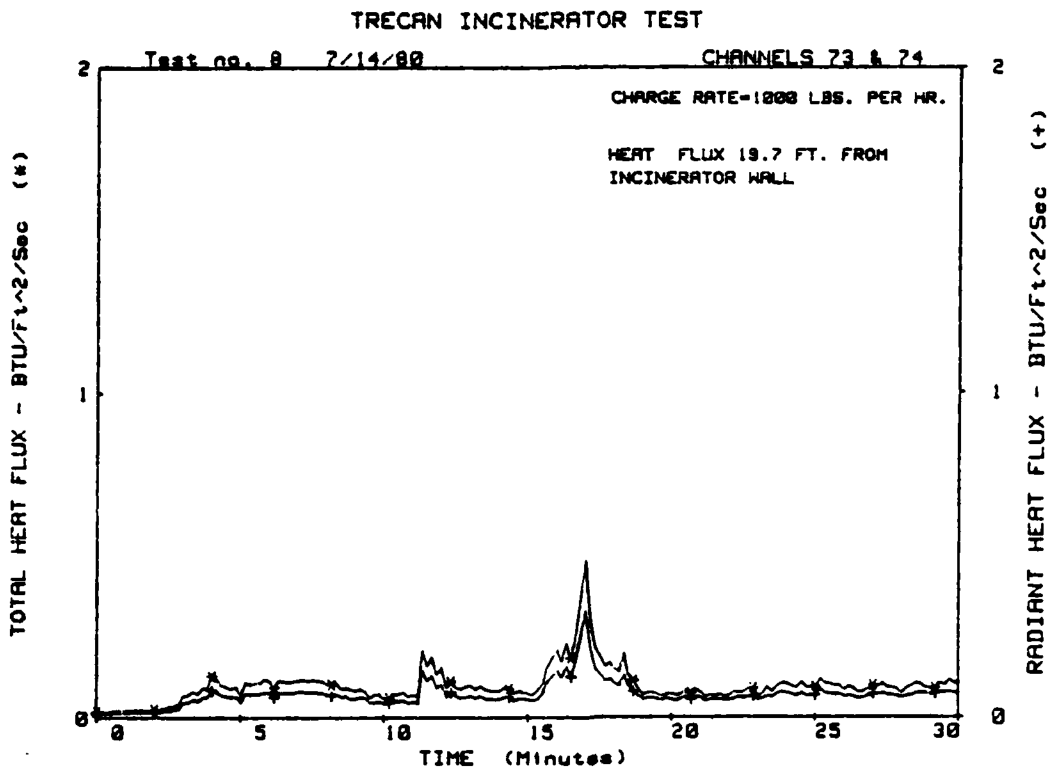
TRECAN INCINERATOR TEST
Test no. 8 7/14/80
CHARGE RATE=1000 LBS. PER HR.
WOOD DEBRIS
OXYGEN CONCENTRATION % (*)
CARBON DIOXIDE CONCENTRATION % (x)
CARBON MONOXIDE CONCENTRATION % (+)
TIME (Minutes)

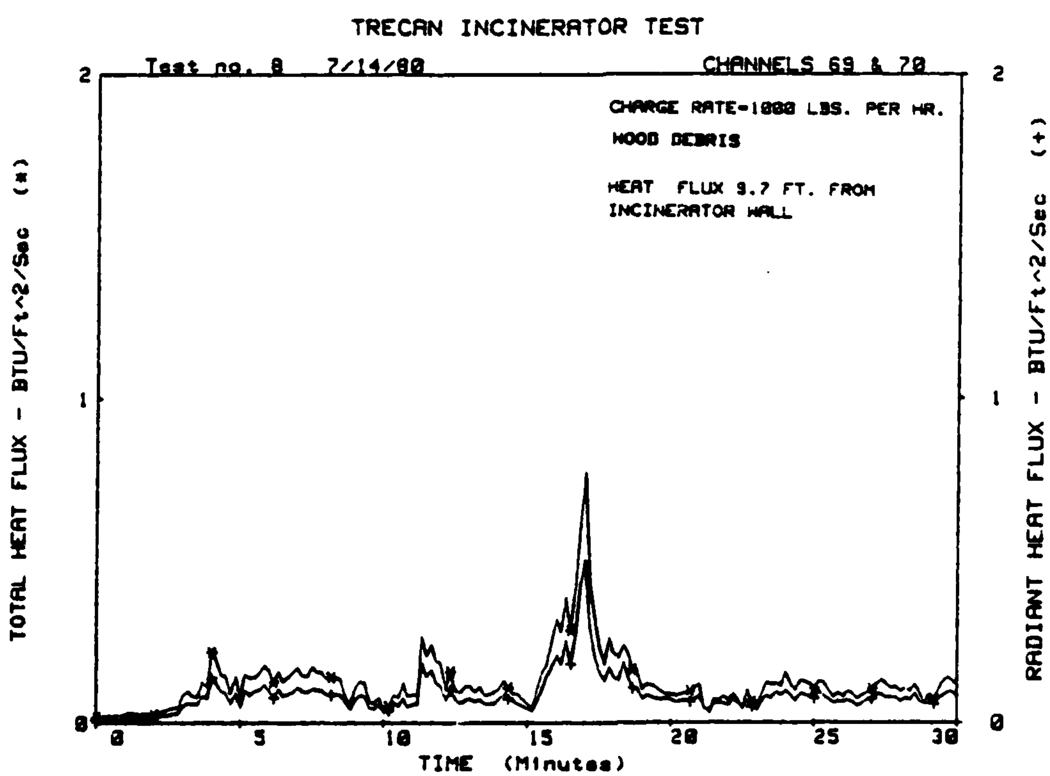


TRECAN INCINERATOR TEST
Test no. 8 7/14/80
Channel no. 64
EXTERIOR SURFACE TEMPERATURE
OF INCINERATOR SECTION
CHARGE RATE=1000 LBS. PER HR.
WOOD DEBRIS
T/C TEMPERATURE (Deg. C)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
TIME (Minutes)



TRECAN INCINERATOR TEST
Test no. 8 7/14/80
AMBIENT TEMPERATURE
T/C TEMPERATURE (Deg. C)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
TIME (Minutes)


TRECAN INCINERATOR TEST
Test no. 8 7/14/80
CHANNELS 73 & 74
CHARGE RATE=1000 LBS. PER HR.
HEAT FLUX 19.7 FT. FROM
INCINERATOR WALL
TOTAL HEAT FLUX - BTU/Ft^2/Sec (*)
RADIANT HEAT FLUX - BTU/Ft^2/Sec (+)
TIME (Minutes)
0
1
2
0
5
10
15
20
25
30


TRECAN INCINERATOR TEST
Test no. 8 7/14/80
CHANNELS 69 & 70
CHARGE RATE=1000 LBS. PER HR.
WOOD DEBRIS
HEAT FLUX 9.7 FT. FROM
INCINERATOR WALL
TOTAL HEAT FLUX - BTU/Ft^2/Sec (*)
RADIANT HEAT FLUX - BTU/Ft^2/Sec (+)
TIME (Minutes)
0
1
2
0
5
10
15
20
25
30

APPENDIX C

Emissions Monitoring and Analysis Report

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

EMISSIONS MONITORING AND ANALYSIS REPORT

FOR

MOBIL RESEARCH & DEVELOPMENT COMPANY

TRECAN INCINERATOR

FIRE & SAFETY TEST DETACHMENT

U.S. COAST GUARD

MOBILE, ALABAMA

July 11 and 12, 1980

P. O. BOX [illegible]

MOBILE, ALABAMA 3661[illegible] • (205) 343-212[illegible]

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INTRODUCTION

INTRODUCTION

Sanders Engineering & Analytical Services, Inc. (SEAS) performed a series of emission tests on a Trecan oily debris incinerator for Mobil Research & Development Corporation. The tests were conducted at the Fire and Safety Test Detachment of the U.S. Coast Guard Base, Mobile, Alabama. The tests were conducted during the week of July 7, 1980.

There were two separate series of tests performed under different operating conditions. Each series of tests consisted of an EPA Method 5, or particulate emission test; an EPA Method 6, oxides of nitrogen test; an EPA Method 8, sulfur dioxide, sulfuric acid mist test; an EPA Method 2, velocity profile test; an EPA Method 9, Visible Emissions test; and a particle size distribution test. The first series of these tests were performed while the incinerator was being charged with straw saturated with #6 oil. The second series of tests were conducted with the incinerator being charged with straw saturated with a 50 percent mixture of #6 oil emulsified in water. A preliminary velocity traverse was performed prior to the charging of any material in the incinerator, to determine the best possible testing arrangement. A summary of these results is presented in the following section.

The tests were conducted by Mr. Joseph C. Sanders, Mr. John Rogers, Mr. Johnny W. Sanders, and Mr. Greg Dobson of Sanders Engineering. The tests were coordinated with Mr. Glen Tolle of Mobil Research & Development Corporation.

Summary and Discussion of Results

The results of the tests are summarized in Tables I-I through I-VI. Complete emission data for each run are included in Section III.

In order to prevent any extraneous particulate matter from being collected on the filters during wash-up, the wash-up procedure was carried out in a relatively clean, draft free sampling van. The filters for each run of the Method 5 test contained many straw fibers which indicated a portion of the straw fed to the incinerator was not being combusted, but was being carried out by the relatively high flow rates through the air curtain. The major problem experienced during the performance of the particulate test were the extremely high temperatures at the sampling location. The stainless steel probe used for sample collection became distorted at these elevated temperatures. The in-stack filter, or Method 17 test, was not able to be completed. The high temperatures caused complete disintegration of the filter assembly.

Discussion of Particulate Sampling Results

Table I-I is a listing of the results of the particulate (EPA Method 5) results. The first column are

TABLE I-I

PARTICULATE TEST RESULTS

MOBIL RESEARCH & DEVELOPMENT CORPORATION
Final Results - Method 5

Test Conditions		#6 Oil	50% Emulsion
Volume of Gas Sampled, SDCF	(V_m)	9.19	7.49
Molecular Weight of Stack Gas, lb/lb-mole	(M_s)	28.8	28.8
Water Vapor in Gas Stream, percent	(B_{ws})	3.5	3.6
Average Stack Gas Velocity, ft/sec	(V_s)	24.1	19.7
Average Stack Gas Temperature, °F	(t_s)	1900.	1300.
Volumetric Flow Rate, SDCFM	(Q_s)	12493.	10897.
Volumetric Flow Rate, ACFM	(Q_a)	54770.	37448.
Particulate Concentration, grs/SDCF	(C_s)	1.6365	0.6480
Particulate Concentration, grs/ACF	(C_a)	0.3556	0.1885
Particulate Mass Rate, lb/hr	(PMR)	175.2	60.5
Percent of Isokinetic	(%I)	107.	103.

the results of the test conducted while firing straw saturated with #6 oil. The second column are the test results while firing straw saturated with a 50-50 emulsion of #6 oil and water. The addition of the water on the second day of testing had two pronounced effects on the emissions of the incinerator:

1) the flow rate was less;
2) the particulate emissions were considerably less.

This is verified by the results of the opacity test conducted during each date. The average opacity for the first date of testing with no water added to the #6 oil, was approximately 85 percent or greater opacity. On the second day when water was added to the #6 oil, the opacity was approximately 40 percent.

A particle sizing test was performed to determine the percentage of particles in specific size ranges. Tables I-II and I-III are the results of the test, and Figure I-1 is a graph of those results. As can be seen from the graph, the percent of particles larger than any specific diameter, was much greater for the test with #6 oil than it was with the 50 percent emulsion. We feel this could best be explained by the fact that the incinerator was, in our opinion, overloaded and could not possibly handle the quantity of straw and oil which was

TABLE I-II

PARTICLE SIZE DISTRIBUTION RESULTS

#6 Oil

MOBIL RESEARCH & DEVELOPMENT CORPORATION

STAGE	FILTER NO.	TARE WEIGHT*	FINAL WEIGHT*	NET WT GAIN*	% IN SIZE RANGE**	SIZE RANGE**	CUMULATIVE % LESS THAN SIZE RANGE	EFFECTIVE CUT DIAMETER**
0	458	0.14615	0.14440	0.00175	21.88	>15.5	78.13	15.5
1	323	0.13705	0.13740	0.00035	4.38	10.4-15.5	73.75	10.4
2	460	0.14460	0.14555	0.00095	11.88	7.0-10.4	61.88	7.0
3	321	0.13735	0.13750	0.00015	1.88	4.5- 7.0	60.00	4.5
4	442	0.14560	0.14605	0.00045	5.63	3.1- 4.5	54.38	3.1
5	319	0.13740	0.13765	0.00025	3.13	1.55- 3.1	51.25	1.55
6	444	0.14550	0.14600	0.00050	6.25	0.96-1.55	45.00	0.96
7	317	0.13675	0.13700	0.00025	3.13	0.66-0.96	41.88	0.66
Backup Filter	230	0.20730	0.21065	0.00335	41.88	0.0-0.66	0.0	0.0
			TOTAL	0.00800				

* -Weight in grams.
** -Weight in microns.

TABLE I-III

PARTICLE SIZE DISTRIBUTION RESULTS

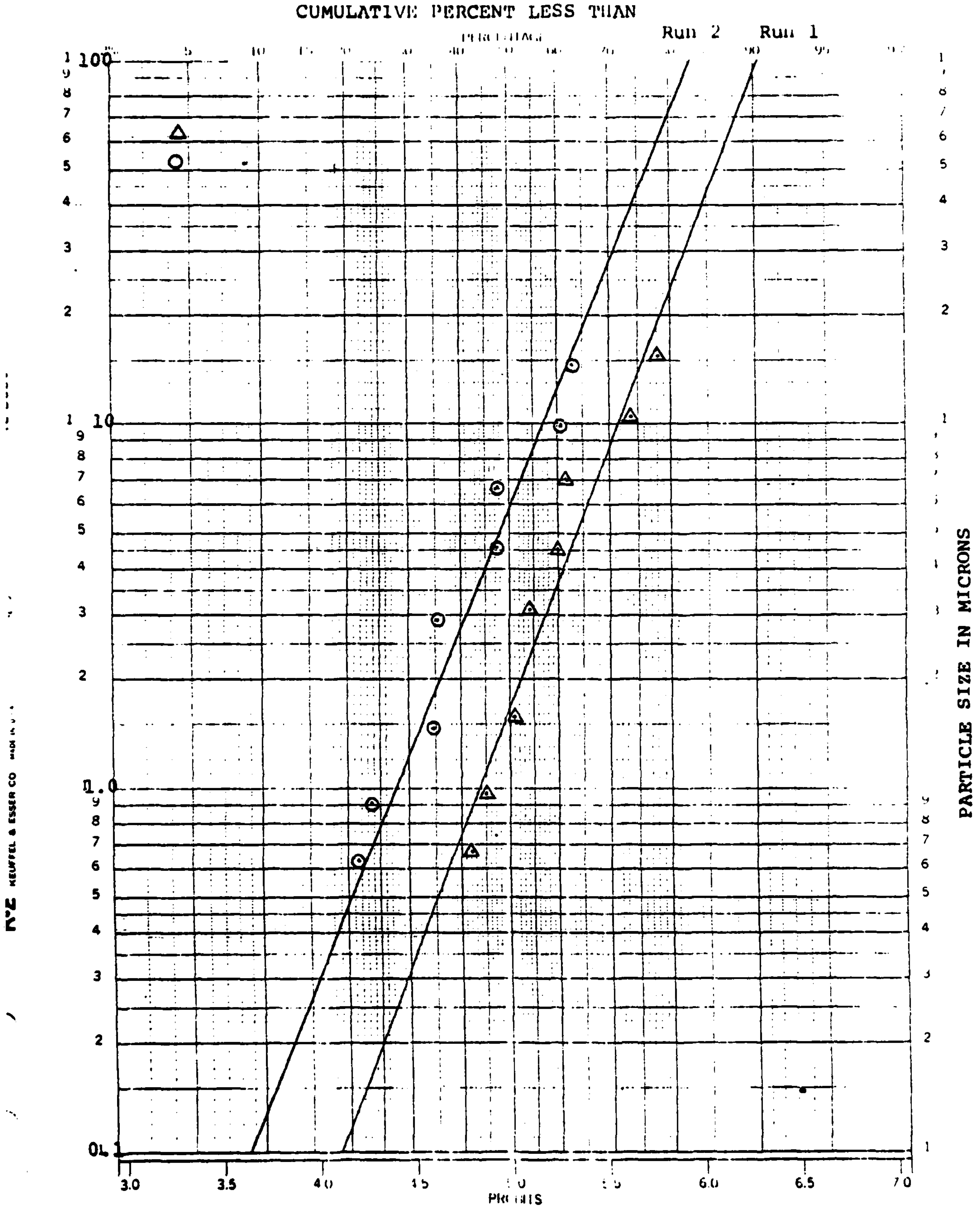
50% Emulsion

MOBIL RESEARCH & DEVELOPMENT CORPORATION

STAGE	FILTER NO.	TARE WEIGHT*	FINAL WEIGHT*	NET WT GAIN*	% IN SIZE RANGE**	SIZE RANGE**	CUMULATIVE % LESS THAN SIZE RANGE	EFFECTIVE CUT DIAMETER**
0	464	0.14550	0.14810	0.0036	37.11	>14.7	62.89	14.7
1	331	0.13780	0.13800	0.0002	2.06	9.8-14.7	60.82	9.8
2	462	0.14480	0.14610	0.0013	13.40	6.7- 9.8	47.42	6.7
3	329	0.13760	0.13760	0.0	0.0	4.6- 6.7	47.42	4.6
4	454	0.14450	0.14565	0.00115	11.86	2.9- 4.6	35.57	2.9
5	327	0.13800	0.13810	0.0001	1.03	1.45- 2.9	34.54	1.45
6	456	0.14500	0.14605	0.00105	10.82	0.91-1.45	23.71	0.91
7	325	0.13780	0.13800	0.0002	2.06	0.63-0.91	21.65	0.63
Backup Filter	231	0.20560	0.20770	0.0021	21.65	0.0-0.63	0.0	0.0
			TOTAL	0.0097				

*-Weight in grams
**-Weight in microns

Figure I-1.



CUMULATIVE PERCENT LESS THAN
PERCENTAGE
Run 2
Run 1
100
10
1.0
0.1
PARTICLE SIZE IN MICRONS
3.0
3.5
4.0
6.0
6.5
7.0
PROBITS
KEUFFEL & ESSER CO.

being fed. The air curtain could not contain the particles, therefore, a large portion of the oil was emitted directly through the curtain and escaped as particulate matter. On the date the 50 percent emulsion of oil and water was fired, the residence time appeared to be considerably longer because of the reduced flow rate and reduced temperatures. This allowed more complete combustion of the oil, giving both a lower emission rate and a smaller particle size, since oil combustion should yield virtually all particles less than 5 microns. This hypothesis is borne out by both the results of the particulate emission test, the opacity observations, and the particle size distribution results.

Because of the design of the manifold supplying the air curtain, there was approximately an 8 inch space on the back wall of the incinerator for which there was no air curtain. This was due to the nozzles extending approximately 8 inches into the incinerator. The great majority of particulates exited the incinerator through this 8 inch gap. The U. S. Coast Guard made a video tape of the air curtain and air flow pattern within the incinerator by use of colored styrofoam material. This tape illustrates the relative quantity of emissions and flow which is lost through this 8 inch gap.

Discussion of Sulfur Oxides Emissions Testing

Table I-IV is a listing of the results of the sulfur dioxide and Table I-V is the listing of the results of the sulfur trioxide or sulfuric acid mist testing performed under each of the two testing circumstances. As can be seen from the results of the sulfur dioxide testing, the sulfur dioxide emissions of the #6 oil test were approximately double those of the 50 percent emulsion test. However, the sulfur trioxide emissions were greater during the 50 percent emulsion test than they were during the #6 oil test. This increase in sulfur trioxide and sulfuric acid mist emissions can be accounted for by the increase in the amount of moisture present in the incinerator. This allowed some of the sulfur dioxide to be converted to sulfur trioxide or sulfuric acid mist. If large quantities of water were introduced into the incinerator, it is felt that the sulfur trioxide emissions would increase proportionately. The nitrogen oxides emissions decreased (see results in Table I-VI) when emulsified oil was fired rather than straight #6 oil. We feel this decrease was primarily due to the reduced quantity of oil fired and the lower temperatures.

TABLE I-IV

SULFUR DIOXIDE TEST RESULTS

MOBIL RESEARCH & DEVELOPMENT CORPORATION

Test Conditions		#6 Oil	50% Emulsion
Volume of Gas Sampled, SDCF	(V_m)	9.342	7.618
Molecular Weight of Stack Gas, Dry	(M_d)	29.3	29.3
Molecular Weight of Stack Gas, Wet	(M_s)	28.9	28.8
Velocity of Stack	(V_s)	23.8	19.6
Volumetric Flow Rate, SDCFM	(Q_s)	12565.	10992.
Volumetric Flow Rate, ACFM	(Q_a)	56825.	37137.
Percent of Isokinetic	(%I)	108.	103.
Sulfur Dioxide Concentration, lb/SDCF	(C_{so_2})	19.4-06	11.6-06
Sulfur Dioxide Concentration, mg/SDCM	(C_{so_2})	310.8	185.8
Sulfur Dioxide Concentration, PPM	(C_{so_2})	117.9	70.5
Pollutant Mass Rate lb/hour	(PPM)	14.6	7.65

M-6&8

TABLE I-V

SULFUR TRIOXIDE TEST RESULTS

MOBIL RESEARCH & DEVELOPMENT CORPORATION

Test Conditions		#6 Oil	50% Emulsion
Volume of Gas Sampled, SDCF	(V_m)	9.342	7.618
Molecular Weight of Stack Gas, Dry	(M_d)	29.3	29.2
Molecular Weight of Stack Gas, Wet	(M_s)	28.9	28.8
Velocity of Stack	(V_s)	23.8	19.6
Volumetric Flow Rate, SDCFM	(Q_s)	12565.	10992.
Volumetric Flow Rate, ACFM	(Q_a)	56825.	37137.
Percent of Isokinetic	(%I)	108.	103.
Sulfur Trioxide Concentration, lb/SDCF	(C_{so_3})	2.1-06	3.0-06
Sulfur Trioxide Concentration, mg/SDCM	(C_{so_3})	34.4	48.6
Sulfur Trioxide Concentration, PPM	(C_{so_3})	10.4	14.7
Pollutant Mass Rate lb/hour	(PPM)	1.62	2.0

M-6&8

TABLE I-VI

NITROGEN OXIDES TEST RESULTS

MOBIL RESEARCH & DEVELOPMENT CORPORATION

Sample No.	Milligrans/ Standard Cubic Meter	Pounds/Dry Standard Cubic Foot (X 10 -6)	Pounds/ Hour	Parts/ Million
* 1	105.18	6.57	4.92	54.97
2	127.83	7.98	5.98	66.80
3	121.04	7.56	5.66	63.25
4	100.81	6.29	4.72	52.68
5	106.05	6.62	4.96	55.42
6	102.62	6.41	4.80	53.63
7	112.00	6.99	5.24	58.53
8	112.16	7.00	5.25	58.61
9	99.99	6.24	4.68	52.26
** 10	74.27	4.64	3.03	38.81
11	78.08	4.87	3.19	40.80
12	84.42	5.27	3.45	44.12
13	83.37	5.20	3.40	43.57
14	88.61	5.53	3.62	46.31
15	95.03	5.93	3.88	49.66
16	88.71	5.53	3.62	46.36
17	93.74	5.85	3.83	48.99
18	98.07	6.12	4.00	51.25
		Average	3.30	

*Samples 1-9 - #6 Oil

**Samples 10-18 - 50% Emulsion

Process Description

The process consists of burning straw and other debris saturated with #6 oil in an open pit type incinerator. The incinerator, 5' x 10' in size, was equipped with an air manifold along the longer axis. This manifold served two purposes: One was to create an effective air curtain over the incinerator, which would aid in the capture and complete combustion of the larger of particles emitted from the incinerator. The other purpose of the manifold was to supply combustion air for the burning process.

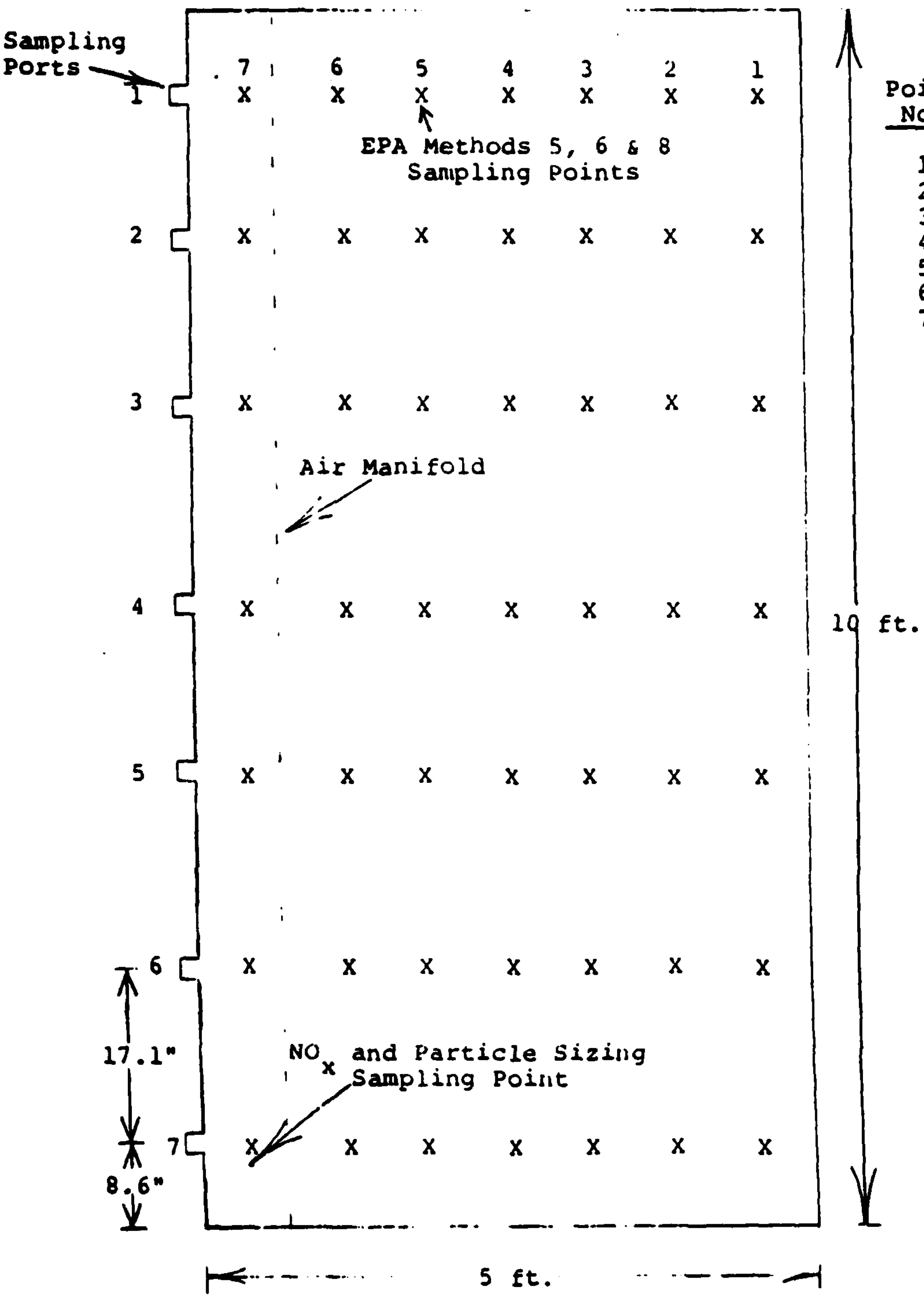
The material was fed to the incinerator over the top by the use of a conveying system.

Sample Point Locations

The sample points for the emission test are shown in Figure I-2. The observer's position for the EPA Method 9 test in relation to the incinerator is shown in Figure I-3.

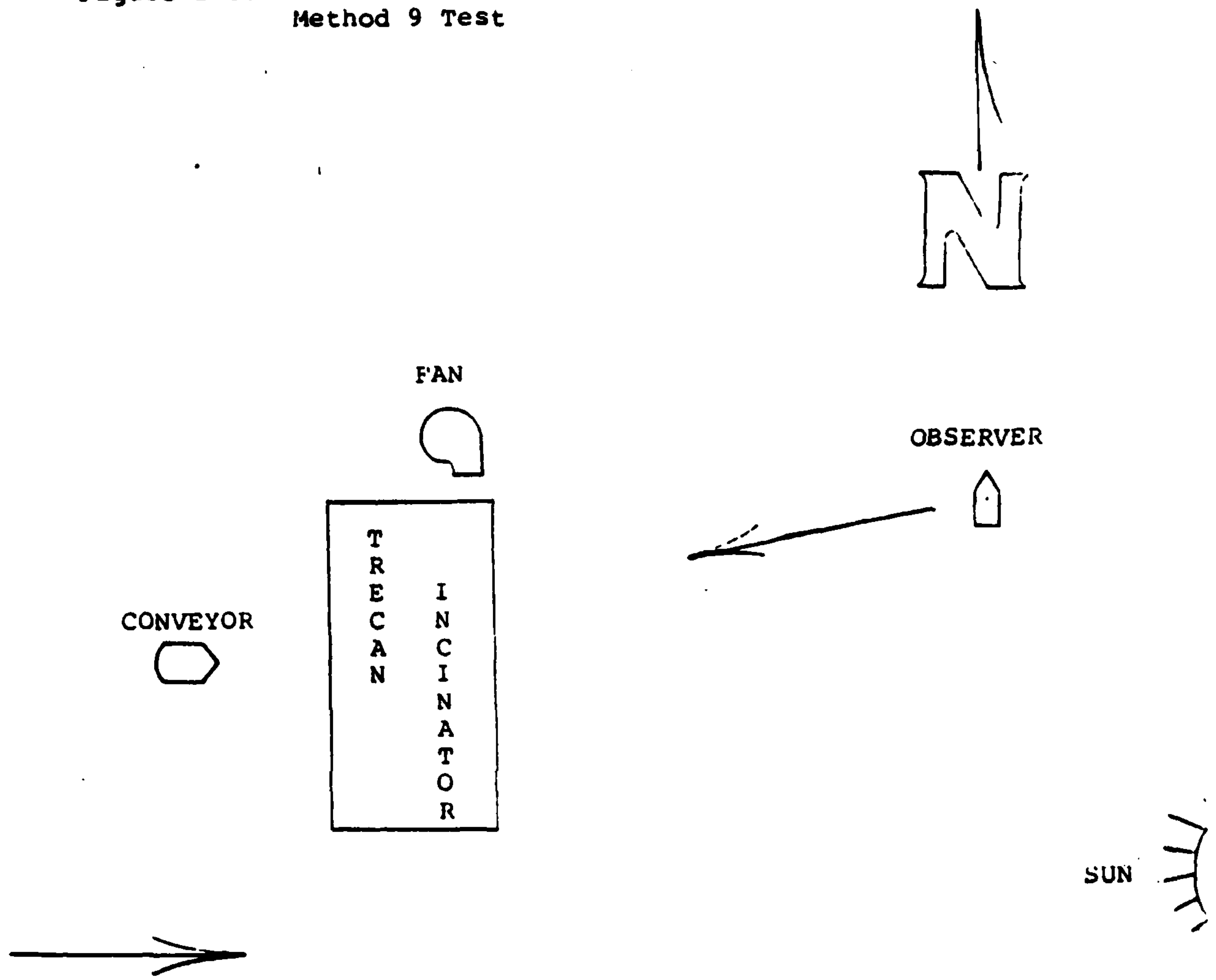
Figure I-2. Sample Point Locations.

MOBIL RESEARCH & DEVELOPMENT CORPORATION



Point No.	Distance in inches
1	4.3
2	12.9
3	21.4
4	30.0
5	38.6
6	47.1
7	55.7

Figure I-3. Position of Observer
Method 9 Test



SECTION II

SAMPLING PROCEDURE

PARTICULATE SAMPLING PROCEDURE

The sample procedure utilized was that approved by the Alabama Air Pollution Control Commission. A brief description of the sampling procedure is as follows:

The sample train was prepared in the following manner: 100 ml of distilled water was added to each of the first two impingers. The third impinger was left empty to act as a moisture trap, and preweighed silica gel was added to the fourth impinger. The train, with the probe, as shown in the following schematic, Figure II-1, was leak checked by plugging the inlet to the nozzle and pulling a 15 inch Hg vacuum. A leakage rate not in excess of 0.02 cfm was considered acceptable.

The inside dimensions of each stack were measured and recorded. The number of sampling points, and the location of these points on a traverse, were determined by the guidelines set forth in the Federal Register, Vol. 36, No. 247, Sec. 60.85, Method 1. These points were then marked on the probe for easy visibility.

A preliminary traverse was conducted to determine the range of velocity head and the pressure of the stack. From these data, the correct nozzle size and the nomograph correction factor were determined.

The probe was attached and the heater was adjusted to provide a temperature of 248° F ± 25° F. The filter heating system was turned on and its temperature adjusted to 248° F ± 25° F. Crushed ice was then placed around the impingers. The nozzle was placed on the first traverse point with the tip pointing directly into the gas steam. The pump was started immediately and the flow was adjusted to isokinetic sampling conditions. After the required time interval had elapsed, the probe was repositioned to the next traverse point and isokinetic sampling was re-established. This was done for each point on the traverse until the run was completed. Readings were taken at each point. When changes in stack conditions occurred, adjustments in sampling flow rate were performed. At the conclusion of each run, the pump was turned off and the final readings were recorded.

Particulate Sample Recovery

Care was exercised in moving the collection train to the sample recovery area to minimize the loss of collected sample, or the gain of extraneous particulate matter. The volume of water in the first three impingers was measured and recorded on the field data sheet. The probe, nozzle, and all sample-exposed surfaces were washed with reagent grade acetone and put into a clean sample bottle. A brush was used to loosen any adhering particulate matter and subsequent washings were put into the container. The filter was carefully removed from the fritted glass support, and placed in a clean Petri dish. The silica gel was removed from the fourth impinger and transferred to its original container. A sample of the acetone used in washing the probe was saved for a blank laboratory analysis.

<u>Particulate Analytical Procedures</u>

The filter and any loose particulate matter were transferred from the Petri dish to a clean, tared glass weighing dish. The filter was placed in a desiccator for at least 24 hours, and then weighed to the nearest 0.1 mg until a constant weight was obtained. The original weight of the filter was deducted, and the weight gain was recorded to the nearest 0.1 mg.

The wash solution was transferred to a clean, tared beaker. The solution was evaporated to dryness, desiccated to a constant weight, and the weight gain was recorded to the nearest 0.1 mg. The silica gel was weighed and the weight gain was recorded to the nearest 0.5 g.

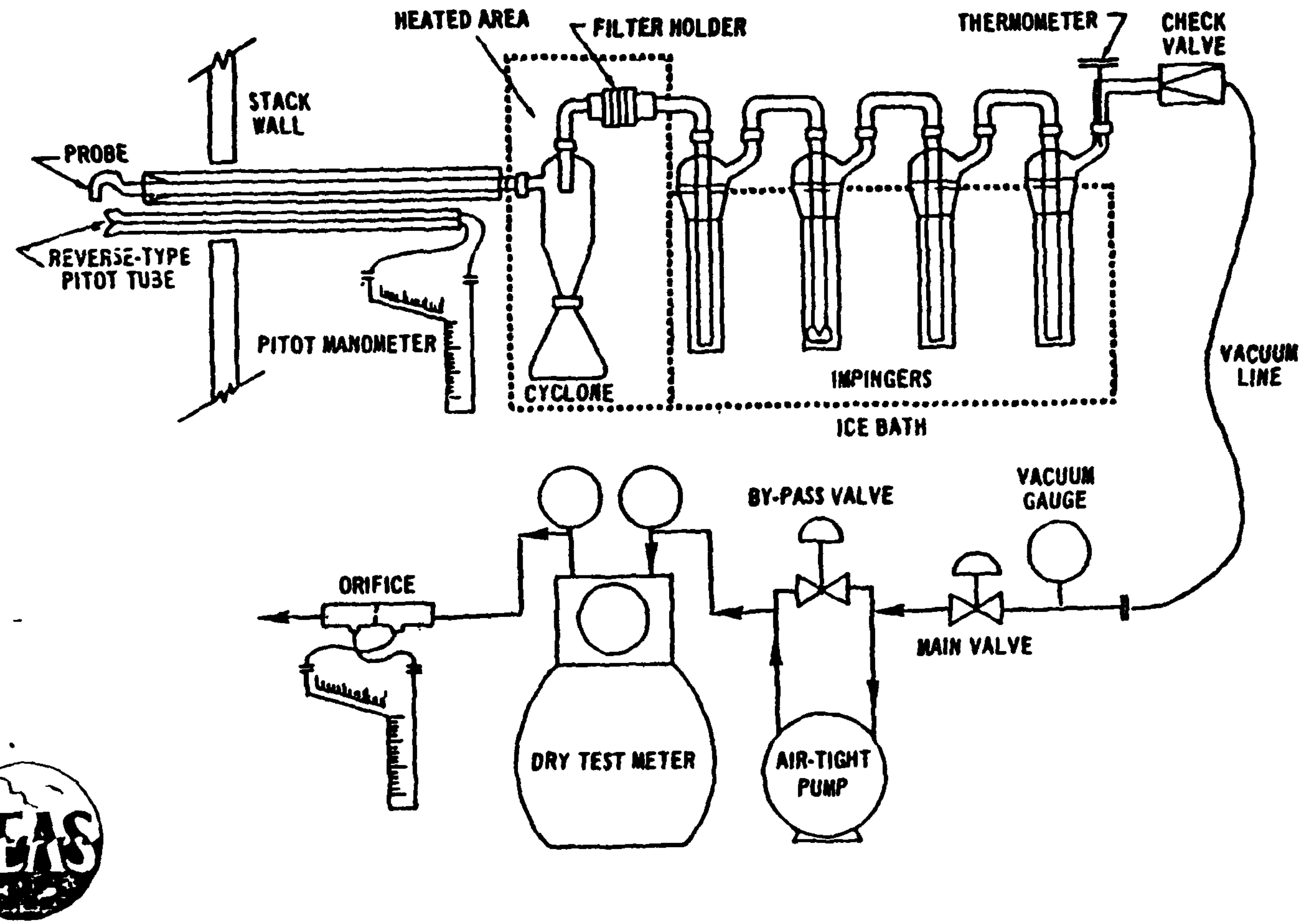


Figure II-1. Particulate sampling train.

SULFUR DIOXIDE EMISSIONS TEST

SAMPLING PROCEDURE

The sample procedure utilized was that approved by the Alabama Air Pollution Control Commission. A brief description of the sampling procedure is as follows:

The sample train was prepared in the following manner: 100 ml of 80 percent Isopropanol was added to the first impinger. To the second and third impingers, 100 ml of 3 percent Hydrogen Peroxide was added, and preweighed silica gel was added to the fourth impinger. The train, with the probe as shown in the following schematic, was leak checked by plugging the inlet and pulling a 15 inch Hg vacuum. A leakage rate not in excess of 0.02 cfm was considered acceptable. (see Figure

Crushed ice was then placed around the impingers. The tip of the probe was placed at the sampling point. The pump was started immediately and the flow was adjusted to a rate less than one cubic foot per minute. During sampling, readings were taken at five minute intervals. After the required sampling time had elapsed, the pump was turned off, the final readings recorded, the probe removed from the stack and a final leak rate was determined. The impingers were then flushed with clean ambient air at the sampling rate for 15 minutes.

Sulfur Dioxide Sample Recovery

After the completion of each run, the collection train was moved to the sample recovery area. The contents of the first impinger were retained. The contents of the second and third impingers were emptied into a leak-free polyethylene bottle. The impingers and connecting tubes were rinsed with distilled water and these washings were added to the storage container.

Sulfur Dioxide Analytical Procedure

The contents of the storage container for each run were transferred to a volumetric flask and diluted with deionized distilled water. An aliquot of this solution was pipetted into a 250 ml erlenmeyer flask, 80 ml of 100 percent Isopropanol and 2 to 4 drops of Thorin indicator were added. This was titrated to a pink end point using 0.01 Normal barium perchlorate. Replicate titrations on each run were repeated until they agreed within one percent, or 0.2 ml, whichever was larger.

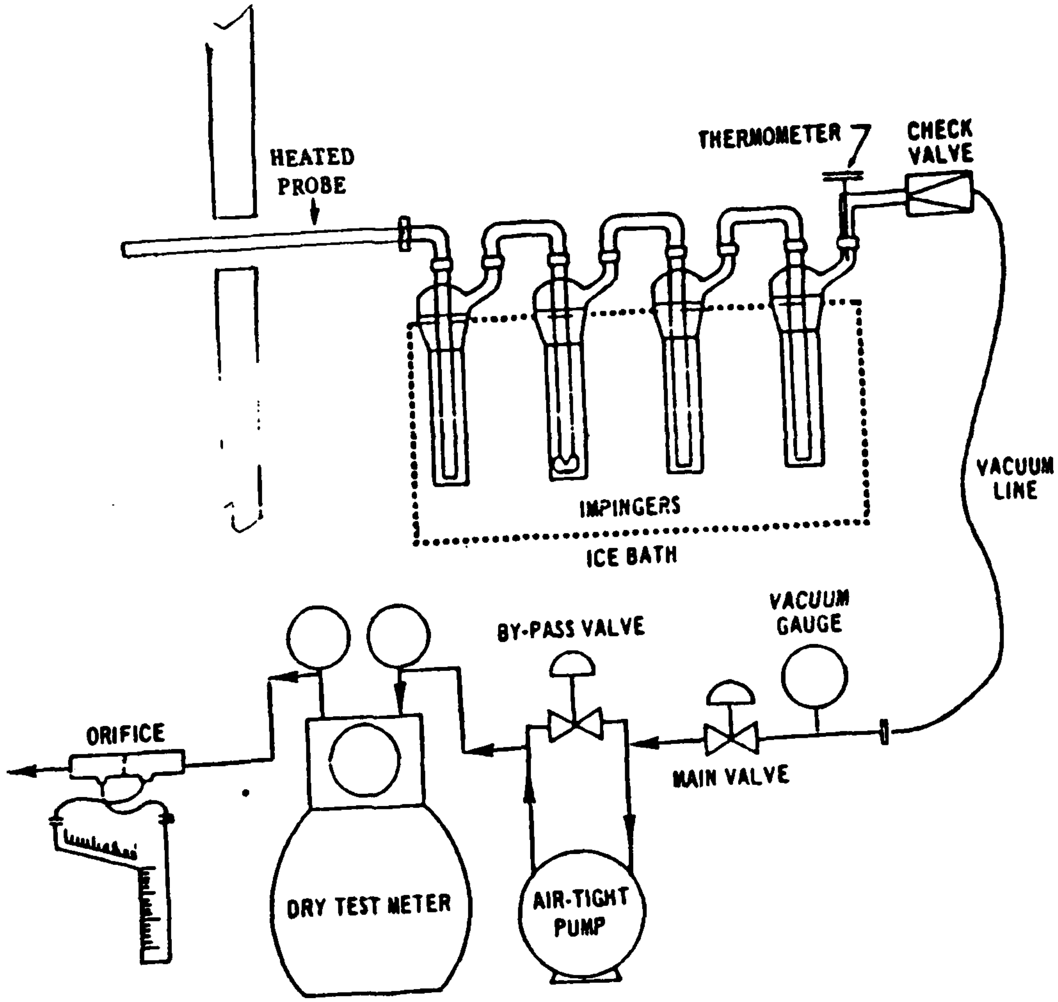


Figure II-2. Sulfur Dioxide Sampling Train

SECTION III

FIELD DATA

NOMENCLATURE

A_n	=	Cross-sectional area of nozzle, ft^2 (3 significant digits)
A_s	=	Area of stack, ft^2
B_{ws}	=	Water vapor in the gas stream, proportion by volume (dimensionless)
C_p	=	Pitot tube coefficient (dimensionless)
c_s	=	Particulate concentration, grains/SDCF
c_{50}	=	Particulate concentration (c_s adjusted to 50% excess air) grains/SDCF
C_{12}	=	Particulate concentration (c_s adjusted to 12% CO_2) grains/SDCF
EA	=	Excess air, %
I	=	Percent of isokinetic sampling
K_m	=	Orifice correction factor (dimensionless)
K_p	=	Pitot tube constant, $85.49\ ft/sec \left[\frac{(lb/lb\text{-}mole)(in.\ H_g)}{(^oR)(in.\ H_2O)}\right]^{1/2}$
L_a	=	Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.02 CFM or 4 percent of the average sampling rate, whichever is less.
L_i	=	Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i = 1, 2, 3 .... n), CFM
L_p	=	Leakage rate observed during the post-test leak check, CFM
m_n	=	Total amount of particulate matter collected, mg
m_a	=	Mass of residue of acetone after evaporation, mg
M_d	=	Molecular weight of stack gas; dry basis, lb/lb-mole
M_s	=	Molecular weight of stack gas; wet basis, lb/lb-mole
P_{bar}	=	Barometric pressure at the sampling site, in. Hg

P_m = Meter pressure, in. Hg

P_s = Absolute stack pressure, in. Hg

P_g = Stack static pressure, in. H_2O

P_{std} = Standard absolute pressure, 29.92 in. Hg

PMR = Particulate mass rate, lb/hr

Q_a = Volumetric flow rate, ACFM

Q_s = Volumetric flow rate, SDCFM

$\overline{t_m}$ = Average temperature of meter, ^oF

$\overline{t_s}$ = Average temperature of stack, ^oF

t_a = Ambient temperature, ^oF

t_{std} = Standard temperature, 68^oF

NOTE: Capital T denotes degrees Rankin.

v_s = Average stack gas velocity, ft/sec

V_a = Volume of acetone blank, ml

V_{aw} = Volume of acetone used in wash, ml

V_{lc} = Total volume of liquid collected in impingers and silica gel, ml

V_m = Volume of gas sample as measured by dry gas meter, ACF

V_{mc} = Volume of gas sample, corrected for leak, ACF

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, SDCF

$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, SCF

V_n = Volume collected at stack conditions through nozzle, ACF

W_a = Weight of residue in acetone wash, mg

Y = Dry gas meter calibration factor (dimensionless)

$\overline{\Delta H}$ = Average pressure difference of orifice, in. H_2O

Δp = Velocity head of stack gas, in. H_2O

$\overline{\sqrt{\Delta p}}$ = Average of the square roots of the velocity pressure, in. H_2O

ΔH_a = Value of ΔH measured for a specific orifice when operated under the following conditions: 0.75 cfm of dry air (M.W. = 29) at 68°F, 29.92 in. Hg.

Θ = Total sampling time, minutes

% CO_2, % O_2, % N_2, % CO - Number % by volume, dry basis from gas analysis.

EQUATIONS

1. $P_s = P_{bar} + \dfrac{P_g}{13.6}$

2. $P_m = P_{bar} + \dfrac{\overline{\Delta H}}{13.6}$

3. $v_s = K_p C_p \overline{\sqrt{\Delta p}} \sqrt{\dfrac{\overline{T}_s}{M_s P_s}}$

4. $V_{m(std)} = 17.64\, V_m Y \left[\dfrac{P_{bar} + \dfrac{\overline{\Delta H}}{13.6}}{\overline{T_m}} \right]$

5. $V_{mc} = V_m - (L_p - L_a)\Theta$

6. $V_{w(std)} = 0.04707\, V_{1c}$

7. $B_{ws} = \dfrac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$

8. $M_d = 0.44(\%CO_2) + 0.32(\%\ O_2) + 0.28(\%\ N_2 + \%\ CO)$

9. $M_s = M_d(1 - B_{ws}) + 18(B_{ws})$

10. $EA = \left[\dfrac{\%O_2 - 0.5(\%CO)}{0.264(\%N_2) - (\%O_2) + 0.5(\%CO)} \right] 100$

11. $Q_a = (v_s)(A_s)(60)$

12. $Q_s = Q_a(1 - B_{ws})\left(\dfrac{528}{\overline{T}_s}\right)\left(\dfrac{P_s}{29.92}\right)$

13. $W_a = \dfrac{m_a\, V_{aw}}{V_a}$

14. $$c_s = 0.0154 \left(\frac{m_n}{V_{m(std)}} \right)$$

15. $$c_{50} = \frac{c_s}{1 - \left[\dfrac{(1.5)(\%O_2) - 0.133(\%N_2) - 0.75(\%CO)}{21} \right]}$$

16. $$c_{12} = c_s \left(\frac{12}{\%\ CO_2} \right)$$

17. $$PMR = (c_s)(Q_s)\left(\frac{60}{7000}\right)$$

18. $$V_n = \frac{\overline{T_s}}{P_s} \left[(0.002669)(V_{1c}) + \frac{V_m\ Y}{\overline{T_m}} \left(P_{bar} + \frac{\overline{\Delta H}}{13.6} \right) \right]$$

19. $$I = \frac{100\ \overline{T_s} \left[(0.002669)(V_{1c}) + \dfrac{V_m\ Y}{\overline{T_m}} \left(P_{bar} + \dfrac{\overline{\Delta H}}{13.6} \right) \right]}{60\ \Theta\ v_s P_s A_n}$$

$$= \frac{100\ V_n}{60\ \Theta\ v_s A_n}$$

TABLE III-I

SUMMARY OF FIELD DATA

MOBILE RESEARCH & DEVELOPMENT CORPORATION - Particulate, Method 5

Test Conditions		#6 Oil	50% Emulsion
Static Pressure in. H_2O	(P_g)	0.2	0.2
Barometric Pressure, in. Hg	(P_{bar})	30.1	30.1
Average Orifice Pressure, in. H_2O	($\overline{\Delta H}$)	0.8	1.17
DGM Calibration	(Y)	1.035	1.035
Average Temperature of meter, ^oF	($\bar{t}_m$)	92.	92.
$\%O_2$		18.5	19.0
$\%CO_2$		2.5	3.0
$\%N_2+\%CO$		79.0	78.0
Volume of Gas Sampled, ACF	(V_m)	9.213	7.506
Total Volume Liquid Collected, ml	(V_{lc})	7.0	6.0
Total Sampling Time, minutes	(θ)	30	23.25
Diameter of Nozzle, in.	(D_n)	0.409	0.409
Average Square Roots of Velocity Pressure, in. H_2O	($\sqrt{\Delta P}$)	0.203	0.193
Pitot Tube Coefficient	(C_p)	0.84	0.84
Temperature of Stack, Average, ^oF	($\bar{t}_s$)	1900.	1300.
Area of Stack, ft^2	(A_s)	39.8	31.63
Particulate Collected, mg	(M_n)	976.58	315.35

TABLE III-II

SUMMARY OF FIELD AND LAB DATA
SULFUR DIOXIDE

MOBIL RESEARCH & DEVELOPMENT CORPORATION

Test Conditions		#6 Oil	50% Emulsion
Static Pressure in. H_2O	(P_g)	0.2	0.2
Barometric Pressure, in. Hg	(P_{bar})	36.6	36.6
Average Orifice Pressure, in. H_2O	($\overline{\Delta H}$)	0.80	1.17
DGM Calibration	(Y)	1.035	1.035
Average Temperature of Meter, ^oF	($\bar{T}_m$)	92	92
$\%O_2$		18.5	19.0
$\%CO_2$		2.9	3.0
$\%N_2+\%CO$		79.0	78.0
Volume of Gas Sampled, ACF	(V_m)	9.213	7.506
Total Volume Liquid Collected, ml	(V_{lc})	7	6
Average Square Roots of Velocity Pressure, in. H_2O	($\sqrt{\Delta P}$)	0.203	0.193
Pitot Tube Coefficient	(C_p)	0.84	0.84
Temperature of Stack ^oF	($\bar{t}_s$)	1900	1300
Area of Stack, ft^2	(A_s)	39.8	31.63
Volume of Titrant, ml	(V_{ot})	29.75	8.10
Volume of Titrant used for Blank, ml	(V_{otb})	0.05	0.05
Normality of Titrant	(N_t)	0.01009	0.01009
Volume of Solution	(V_s)	214	231
Volume of Aliquot, ml	(V_a)	25	15
Diameter of Nozzle, in.	(D_n)	0.409	0.409
Time, min.		30	23.25
($1=SO_2$, $0=SO_3$)		1	1

TABLE III-III

SUMMARY OF FIELD AND LAB DATA
SULFUR TRIOXIDE

MOBIL RESEARCH & DEVELOPMENT CORPORATION

Test Conditions		#6 Oil	50% Emulsion
Static Pressure in. H_2O	(P_g)	0.2	0.2
Barometric Pressure, in. Hg	(P_{bar})	36.6	36.6
Average Orifice Pressure, in. H_2O	$(\overline{\Delta H})$	0.80	1.17
DGM Calibration	(Y)	1.035	1.035
Average Temperature of Meter, ^oF	$(\bar{T}_m)$	92	92
$\%O_2$		18.5	19.0
$\%CO_2$		2.9	3.0
$\%N_2$+%CO		79.0	78.0
Volume of Gas Sampled, ACF	(V_m)	9.213	7.506
Total Volume Liquid Collected, ml	(V_{lc})	7	6
Average Square Roots of Velocity Pressure, in. H_2O	$(\sqrt{\Delta P})$	0.203	0.193
Pitot Tube Coefficient	(C_p)	0.84	0.84
Temperature of Stack ^oF	$(\bar{T}_s)$	1900	1300
Area of Stack, ft^2	(A_s)	39.8	31.63
Volume of Titrant, ml	(V_t)	5.1	5.8
Volume of Titrant used for Blank, ml	(V_{tb})	0.05	0.05
Normality of Titrant	(N_t)	0.01009	0.01009
Volume of Solution	(V_s)	91	92
Volume of Aliquot, ml	(V_a)	25	25
Diameter of Nozzle, in.	(D_n)	0.409	0.409
Time, min.		30	23.25
$(1=SO_2,\ 0=SO_3)$		0	0

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

SEAS

PLANT /S [illegible]
SAMPLING SITE
TEST OPERATOR [illegible] DATE 7/11/90
RUN NO. M-[illegible]-1
TIME BEGIN ____ TIME END ____
PROBE # ____ METER BOX # ~~460~~ C-133
C_p .84

GAS ANALYSIS: CO_2 2.5
O_2 18.5
$\%N_2+\%CO$

METER READING
FINAL 339.217
INITIAL 330.004
NET 9.213

LOST DURING TRANSPORT, ml
ACETONE BLANK VOLUME, ml
ACETONE WASH VOLUME, ml
ACETONE WASH BLANK, mg/ml

AMBIENT TEMP. ____ °F
BAROMETRIC PRESS. 30.1 in. Hg
STATIC PRESSURE ____ in. H_2O
NOZZLE CALIBRATION - PRETEST ____ POST TEST ____
[illegible] in. ____ in.
[illegible] in. ____ in.
____ in. ____ in.
AVERAGE DIAMETER [illegible] in. ____ in.
PROBE HEATER SETTING
PROBE LINER MATERIAL
LENGTH 10 ft.

NOMOGRAPH VALUES: ΔH@ 1.92, T_m 95
$\%H_2O$ 2, P_s/P_m 1.0
ΔP ref ____ c ____, T_s [illegible]

K_{1} = 0.0103

LEAK CHECKS

15 " Hg ✓ Impact

SYSTEM <0.005 CFM PITOT ✓ Static

WEIGHT OF PARTICULATE COLLECTED

Container Number	Final Weight	Tare Weight	Weight Gain
Filter No. 819	0.77130	0.66247	0.10883
Container No. 8	63.9476	63.07985	0.86775
TOTAL			0.97658
		Less Acetone Blank	
		Weight of Particulate Matter	976.58

SCHEMATIC OF STACK X-SECTION
DISTANCE UPSTREAM ____ ft.
DISTANCE DOWNSTREAM ____ ft.
STACK DIAMETER 5x10 ft in.

VOLUME OF LIQUID WATER COLLECTED

	Impinger Volume* ml.	Impinger Volume* ml.	Impinger Volume* ml.	Silica Gel Weight g.
Final				
Initial				667.95
Liquid Collected				
Total Volume Collected				

*CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1 g/ml):

Page 1 of 4

$\frac{\text{INCREASE, g}}{\text{1 g/ml}}$ = VOLUME WATER, ml

11.9

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
1-1	7:54	333.004	.031	.54	<150°				85	82	
1-2		333.642	.031	.54					86	88	
1-3		333.752	.026	.45					86	84	
1-4			.010	.18					88	84	
1-5			.016	.27					89	84	
1-6			.010	.18					90	85	
1-7			.010	.18					90	85	
2-1			.005	.09					90	85	
2-2			.01	.18					91	85	
2-3			.016	.27					91	85	
2-4			.01	.18					91	86	
2-5			.016	.27					92	87	
2-6			.078	1.66					93	87	
2-7		—	.042	.72					93	87	
3-1			0	0					—	—	
3-2			0	0					—	—	
3-3			.005	.09					95	88	
3-4			.078	1.35					95	89	
3-5			.063	1.08					96	90	
3-6			.115	1.99					96	90	
3-7			.089	1.53					96	90	
4-1			.052	0.90					97	90	
4-2			0						—	—	
4-3			0						—	—	

AVERAGES:

COMPANY Coast Guard DATE 7/11/80

STACK # ______ RUN # 1 PAGE 3 OF 4

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
4-4			0						—	—	
4-5			.037	.63					98	90	
4-6			.021	.76					98	90	
4-7			.052	.90					98	90	
5-1			.078	1.35					99	89	
5-2			.235	.45					99	89	
5-3			0						—	—	
5-4			0						—	—	
5-5			.005	.09					99	90	
5-6			.078	1.35					99	90	
5-7			.026	.45					99	90	
6-1			.037	.63					100	90	
6-2			.052	0.90					100	90	
6-3			0						—	—	
6-4			0						—	—	
6-5			.052	0.9					100	90	
6-6			.084	1.53					101	90	
6-7			.094	1.62					98	90	
7-1			.016	0.27					99	90	
7-2			.010	.18					101	90	
7-3			0						—	—	
7-4			.005	.09					101	89	
7-5			.105	1.80					102	90	
7-6			.183	3.16					102	91	

AVERAGES:

COMPANY Coast Guard DATE 7/11/80

STACK # ______ RUN # 1 PAGE 3 OF 4

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	OUT	VAC. in. Hg
7.5			.105	1.80					101	89	
		339.217									

AVERAGES:

COMPANY Coast Guard DATE 7/11/80

STACK # ______ RUN # 1 PAGE 4 OF 4

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

PLANT USCG
SAMPLING SITE Inc.
TEST OPERATOR [illegible] DATE 7/12/80
RUN NO. 2
TIME BEGIN ______ TIME END ______
PROBE # ______ METER BOX # ~~460~~ C-133
C_p 0.84

GAS ANALYSIS: CO_2 ~~19.0~~ 3.0
O_2 ~~3~~ 19.0
$\%N_2+\%CO$ ______

METER READING
FINAL 3[illegible]
INITIAL 349.750
NET 7.506

LOST DURING TRANSPORT, ml ______
ACETONE BLANK VOLUME, ml ______
ACETONE WASH VOLUME, ml ______
ACETONE WASH BLANK, mg/ml ______

AMBIENT TEMP. ______ °F
BAROMETRIC PRESS. 30.1 in. Hg
STATIC PRESSURE ______ in. H_2O
NOZZLE CALIBRATION - PRETEST ______ in. POST TEST ______ in.
AVERAGE DIAMETER .409 in.
PROBE HEATER SETTING ______
PROBE LINER MATERIAL SS
LENGTH 10 ft.

NOMOGRAPH VALUES: ΔH@ 1.92, T_m 90
%H_2O 2, P_s/P_m 1.0
ΔP ref ______ c ______, T_s 1001
Km = 0.6717

LEAK CHECKS
15 " Hg ✓ Impact
SYSTEM 0.007 CFM PITOT ✓ Static

WEIGHT OF PARTICULATE COLLECTED

Container Number	Final Weight	Tare Weight	Weight Gain
Filter No. 821	0.77760	0.65925	0.11835
Container No. 9	65.0670	64.8700	0.19700
TOTAL			0.31535
Less Acetone Blank			
Weight of Particulate Matter			315.35

SCHEMATIC OF STACK X-SECTION
DISTANCE UPSTREAM ____ ft.
DISTANCE DOWNSTREAM ____ ft.
STACK DIAMETER ____ in.

VOLUME OF LIQUID WATER COLLECTED

	Impinger Volume* ml.	Impinger Volume* ml.	Impinger Volume* ml.	Silica Gel Weight g.
Final				
Initial				
Liquid Collected				
Total Volume Collected				

*CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1 g/ml):

$$\frac{\text{INCREASE, g}}{1\ \text{g/ml}} = \text{VOLUME WATER, ml}$$

Page___of___

SEAS

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
1-1		349.732	0								
1-2			0								
1-3			0								
1-4			0								
1-5			.069	2.0					88	84	
1-6			.052	1.5					89	84	
1-7			.052	1.5					90	84	
2-1											
2-2											
2-3											
2-4			.004	0.12					92	85	
2-5			.035	1.0					93	85	
2-6			.043	1.25					92	85	
2-7			.060	1.75					92	85	
3-1			0						—		
3-2			0						—		
3-3			.013	.37					92	87	
3-4			.009	.25					92	87	
3-5			.043	1.25					92	87	
3-6			.022	.60					93	88	
3-7			.087	2.50					93	88	
4-1			.009	.25					93	88	
4-2			.004	.12					93	88	
4-3			0						—		

AVERAGES:

COMPANY Coast Guard **DATE** 7/12/80

STACK # ______ **RUN #** 2 **PAGE** 2 **OF** 4

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP inH_2O	ORIFICE HEAD ΔH $in.H_2O$	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
4-4		.	.004	0.12					96	88	
4-5			.130	3.7					96	88	
4-6			.095	2.76					97	89	
4-7			.087	2.50					97	89	
5-1			.017	0.50					97	89	
5-2			0						—		
5-3			0						—		
5-4			.004	0.12					97	89	
5-5			.013	0.37					98	89	
5-6			.035	1.0					98	90	
5-7			.078	2.26					98	90	
6-1			.004	0.12					98	90	
6-2			0						—		
6-3			0						—		
6-4			0						—		
6-5			.026	0.75					99	91	
6-6			.065	1.88					100	91	
6-7			.056	1.6					100	91	
7-1			0								
7-2			0								
7-3			0								
7-4			.013	0.37					101	91	
7-5			.087	2.5					101	91	
7-6			.095	2.76					102	91	

AVERAGES:

COMPANY Coast Guard DATE 7/12/80

STACK # ________ RUN # 2 PAGE 3 OF 4

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
7-7			.082	2.38					102	91	
		357.256									

AVERAGES:

COMPANY Coast Guard DATE 7/12/80

STACK # ______ RUN # 2 PAGE 4 OF 4

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

SEAS

PLANT Mobil Resource + Lab.
SAMPLING SITE Coast Guard
TEST OPERATOR ________ DATE 7/9/80
RUN NO. 1
TIME BEGIN ________ TIME END ________
PROBE # ________ METER BOX # ________
IMP. BOX # ________ C_p 0.84

GAS ANALYSIS: CO_2 0
O_2 21.0
$\%N_2 + \%CO$ 79.0

METER READING
FINAL ________
INITIAL ________
NET ________

LOST DURING TRANSPORT, ml ________
ACETONE BLANK VOLUME, ml ________
ACETONE WASH VOLUME, ml ________
ACETONE WASH BLANK, mg/ml ________

AMBIENT TEMP. ________ °F
BAROMETRIC PRESS. 30.10 in. Hg
STATIC PRESSURE +0.2 in. H_2O
NOZZLE CALIBRATION - PRETEST ________ in. POST TEST ________ in.
________ in. ________ in.
________ in. ________ in.
AVERAGE DIAMETER .409 in. ________ in.
PROBE HEATER SETTING ________
PROBE LINER MATERIAL ________
LENGTH ________ ft.

NOMOGRAPH VALUES: $\Delta H@$ ________, T_m ________
$\%H_2O$ ________, P_s/P_m ________
ΔP ref ________ c ________, T_s ________

LEAK CHECKS

SYSTEM ________ " Hg ________ CFM
PITOT ________ Impact ________ Static

SCHEMATIC OF STACK X-SECTION

DISTANCE UPSTREAM ____ ft.
DISTANCE DOWNSTREAM ____ ft.
STACK DIAMETER ____ in.

WEIGHT OF PARTICULATE COLLECTED

Container Number	Final Weight	Tare Weight	Weight Gain
Filter No.			
Container No.			
TOTAL			
		Less Acetone Blank	
		Weight of Particulate Matter	

VOLUME OF LIQUID WATER COLLECTED

	Impinger Volume* ml.	Impinger Volume* ml.	Impinger Volume* ml.	Silica Gel Weight g.
Final				
Initial				
Liquid Collected				
			Total Volume Collected	

*CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1 g/ml):

Page 1 of 2

$$\frac{\text{INCREASE, g}}{1\ \text{g/ml}} = \text{VOLUME WATER, ml}$$

PORT # / POINT#	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP in H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	~~PROBE~~ Port	HOT BOX	~~IMP.~~ ΔP	GAS METER IN	GAS METER OUT	VAC. in. Hg
4-1			-.03			2-1		+.012			
4-2			-.02			2-2		+.06			
4-3			0			2-3		-.06			
4-4			0			2-4		-.10			
4-5			0			2-5		-.10			
4-6			0			2-6		-.40			
4-7			0			2-7		-.35			
4-8			-.03			2-8		-.60			
4-9			+.06			2-9		0			
4-10			+.09			2-10		+.024			
3-10			+.15			1-10		+.021			
3-9			+.17			1-9		+.018			
3-8			+.17			1-8		+.015			
3-7			+.07			1-7		+.012			
3-6			-.07			1-6		+.018			
3-5			-.06			1-5		+.021			
3-4			-.03			1-4		+.036			
3-3			-.03			1-3		+.033			
3-2			-.04			1-2		+.03			
3-1			-.03			1-1		+.03			

AVERAGES:

COMPANY Mobil Resource DATE 7/9/80

STACK # Coast Guard RUN # 1 PAGE 2 OF 2

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

PLANT Mobil Resources + Lab.
SAMPLING SITE Coast Guard
TEST OPERATOR ______ DATE 7/9/80
RUN NO. 2
TIME BEGIN ______ TIME END ______
PROBE # ______ METER BOX # ______
IMP. BOX # ______ C_p 0.84

GAS ANALYSIS: CO_2 0
O_2 21.0
$\%N_2 + \%CO$ 79.0

METER READING
FINAL ______
INITIAL ______
NET ______

LOST DURING TRANSPORT, ml ______
ACETONE BLANK VOLUME, ml ______
ACETONE WASH VOLUME, ml ______
ACETONE WASH BLANK, mg/ml ______

AMBIENT TEMP. ______ °F
BAROMETRIC PRESS. 30.10 in. Hg
STATIC PRESSURE +0.2 in. H_2O
NOZZLE CALIBRATION - PRETEST ______ in. POST TEST ______ in.
______ in. ______ in.
______ in. ______ in.
AVERAGE DIAMETER .409 in. ______ in.
PROBE HEATER SETTING ______
PROBE LINER MATERIAL ______
LENGTH ______ ft.

NOMOGRAPH VALUES: ΔH@ ______, T_m ______
$\%H_2O$ ______, P_s/P_m ______
ΔP ref ______ c ______, T_s ______

LEAK CHECKS

SYSTEM ______ " Hg ______ CFM
PITOT ______ Impact ______ Static

SCHEMATIC OF STACK X-SECTION
DISTANCE UPSTREAM ______ ft.
DISTANCE DOWNSTREAM ______ ft.
STACK DIAMETER ______ in.

WEIGHT OF PARTICULATE COLLECTED

Container Number	Final Weight	Tare Weight	Weight Gain
Filter No.			
Container No.			
TOTAL			
		Less Acetone Blank	
		Weight of Particulate Matter	

VOLUME OF LIQUID WATER COLLECTED

	Impinger Volume* ml.	Impinger Volume* ml.	Impinger Volume* ml.	Silica Gel Weight g.
Final				
Initial				
Liquid Collected				
			Total Volume Collected	

*CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1 g/ml):

$$\frac{\text{INCREASE, g}}{1\ \text{g/ml}} = \text{VOLUME WATER, ml}$$

Page 1 of 2

PORT # / POINT #	TIME	GAS METER VOL. (cu ft)	VEL. HEAD ΔP inH_2O	ORIFICE HEAD ΔH $in.H_2O$	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. Hg
1-1			-.03								
1-2			-.03								
1-3			-.05								
1-4			-.07								
1-5			+.034								
1-6			+.02								
2-6			+.02								
2-5			+.027								
2-4			0								
2-3			-.03								
2-2			-.05								
2-1			-.01								
3-1			-.04								
3-2			-.06								
3-3			-.15								
3-4			-.1								
3-5			+.02								
3-6			+.016								
4-6			+.016								
4-5			+.027								
4-4			-.17								
4-3			-.06								
4-2			-.05								
4-1			-.05								

AVERAGES:

COMPANY Mobil Res. DATE 7/9/80

STACK # Coast Guard RUN # 2 PAGE 2 OF 2

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC.
800 DOWNTOWNER BLVD. SUITE 109 • P. O. BOX 160404 MOBILE, ALABAMA 36616 • 205 / 343-2120

RUN 1

Date: 7/11/80

Facility Name: US CG

Clock Time:

Location:

Wind Direction: NW

Type Facility: Line

Wind Speed:

Emission Source: [illegible]

Ambient Temperature: 95°F

Control Device: Air Curtain

Sky Condition: Clear

Stack Height: 10'

Sky Color: Blue

Estimated Distance from Source: 30'

Plume Background:

Direction from Source: NE

Color of Plume: BLACK

X Change

	Seconds				Steam Plume		
MIN	00	15	30	45	Attached	Detached	Comments
0	*100	80	85	80			
1	85	90	80	80			
2	95	90	80	80			
3	*100	80	85	75			
4	80	75	80	75			
5	70	75	80	75			
FLAME 6	*100	FLAME 100	FLAME 100	FLAME 85			
7	75	70	75	70			
8	65	70	70	65			
9	60	60	* FLAME 100	FLAME 100	Flame Below nozzle		
10	90	75	40	50			
11	45	45	50	40			

Readings Ranged from ____% to ____% Opacity

Six-Minute Average (24 Consecutive Observations): ____% Opacity

Observer and Certification Date ____________ Signature ____________

APC 09
5/77

SEAS

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC.

800 DOWNTOWNER BLVD. SUITE 109 • P. O. BOX 160404 MOBILE, ALABAMA 36616 • 205 / 343-3120

Date: 7/12/90

Facility Name: Coast Guard

Clock Time: 7:25 AM

Location:

Wind Direction: From West

Type Facility: Air Station District

Wind Speed: 5 MPH

Emission Source:

Ambient Temperature: 77

Control Device:

Sky Condition: Clear

Stack Height:

Sky Color: Blue

Estimated Distance from Source: 100

Plume Background: Blue Sky

Direction from Source: 70°

Color of Plume: Brown

	Seconds				Steam Plume		
MIN	00	15	30	45	Attached	Detached	Comments
0	30	20	20	10			
1	10	10	15	15			
2	15	20	20	35	— Start Ball		
3	20	25	25	25			
4	15	15	15	10			
5	10	20	10	15			
Start 6	15	15	15	10			One or greater opacity
7	10	10	15	15			slight along
8	20	20	25	20			
End 9	20	15	25	25			
10	5	10	10	15			
11	20	25	25	25			

Readings Ranged from _____% to _____% Opacity

Six-Minute Average (24 Consecutive Observations): _____% Opacity

Observer and Certification Date ____________ Signature Joseph C. Sanders

APC 09

PARTICLE SIZE DISTRIBUTION

PLANT Mobil Oil
SAMPLING SITE Inc.
TEST OPERATOR JCS DATE ______
RUN NO. 1
TIME BEGIN ______ TIME END ______
PROBE # ______ METER BOX # 460
C_p 0.84

GAS ANALYSIS: CO_2 ______
O_2 ______
CO ______

METER READING
FINAL 339.756
INITIAL 338.642
NET 1.114

AMBIENT TEMP. ______ °F
BAROMETRIC PRESS. 30.1 in. Hg
STATIC PRESSURE + 0.2 in. H_2O
NOZZLE CALIBRATION - PRETEST POST TEST
______ in. ______ in.
______ in. ______ in.
______ in. ______ in.
AVERAGE DIAMETER .197 in. ______ in.
PROBE HEATER SETTING ______
PROBE LINER MATERIAL ______
LENGTH ______ ft.

NOMOGRAPH VALUES: ΔH@ ______, T_m ______
%H2O ______, P_s/P_m ______
c ______, T_s ______
ΔP ref ______

Page 1 Of 2

ANDERSEN PARTICLE SIZING

Port Point	Clock Time	Gas Meter Vol.	Vel. Head ΔP	Orifice Head ΔH	Stack Temp. °F	Gas Meter In	Gas Meter Out	Stage	Filter Stage/ Top of Plate#*	Filter No.	Cont. No.
	10 45 2	335.602	0.20 ~~1.06~~	0.111		88	85	0	1	458	
	10	334.0	0.2	0.111		87	84	1	2	323	
		334.4	0.2	0.111		88	84	2	3	460	
		334.756						3	4	321	
								4	5	442	
								5	6	319	
	8 min							6	7	444	
								7	8	317	
								Back-Up	Back-Up	230	
			1 Bar (50 ft)		every 3 min						

2

*NOTE - Nozzel, precollected and stage 0 goes with filter on top of plate 1 into cont. X-0. Wash these items with Acetone into sample bottle.

COMPANY ______ DATE Dn. 187

STACK # ______ RUN # 1 PAGE 2 OF 2

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC

PLANT Coast Guard
SAMPLING SITE Iron
TEST OPERATOR JCS DATE
RUN NO. 2
TIME BEGIN TIME END
PROBE # METER BOX # 860
C_p

GAS ANALYSIS: CO_2
O_2
$\%N_2+\%CO$

METER READING
FINAL 349.750
INITIAL 347.710
NET 2.04

LOST DURING TRANSPORT, ml
ACETONE BLANK VOLUME, ml
ACETONE WASH VOLUME, ml
ACETONE WASH BLANK, mg/ml

AMBIENT TEMP. °F
BAROMETRIC PRESS. 30.10 in. Hg
STATIC PRESSURE in. H_2O
NOZZLE CALIBRATION - PRETEST POST TEST
in. in.
in. in.
in. in.
AVERAGE DIAMETER .188 in. in.
PROBE HEATER SETTING
PROBE LINER MATERIAL
LENGTH ft.

NOMOGRAPH VALUES: $\Delta H@$, T_m
$\%H_2O$, P_s/P_m
ΔP ref c , T_s

LEAK CHECKS

SYSTEM	" Hg	PITOT	Impact
	CFM		Static

SCHEMATIC OF STACK X-SECTION
DISTANCE UPSTREAM ft.
DISTANCE DOWNSTREAM ft.
STACK DIAMETER in.

WEIGHT OF PARTICULATE COLLECTED

Container Number	Final Weight	Tare Weight	Weight Gain
Filter No.			
Container No.			
TOTAL			
		Less Acetone Blank	
		Weight of Particulate Matter	

VOLUME OF LIQUID WATER COLLECTED

Page 1 of 2

ANDERSEN PARTICLE SIZING

Port / Point	Clock Time	Gas Meter Vol.	Vel. Head P	Orifice Head H	Stack Temp. °F	Gas Meter In	Gas Meter Out	Stage	* Filter Stage/ Top of Plate#	Filter No.	Cont. No.
4-5	9:40	347.76	.3	.168	100	81	77	0	1	964	
4-5	9:42		.3	.168	100	83	78	1	2	331	
	944	348.7	.3	.168		84	79	2	3	462	
	946	348.9	.3	.164		86	80	3	4	329	
	948							4	5	494	
off	950	349.760						5	6	327	
								6	7	436	
								7	8	325	
								Back-Up	Back-Up	231	
		50% Emulsion									

*NOTE - Nozzel, precollected and stage 0 goes with filter on top of plate 1 into cont. X-0. Wash these items with Acetone into sample bottle.

COMPANY Coal Gear DATE 7/16/80

STACK # ______ RUN # 2 PAGE 2 OF 2

SECTION IV

CALIBRATIONS

METER CALIBRATION FORM - WTM

Date March 20, 1980 Box No. LSI-460

Test Condition: ΔH ______ in. H_2O Maximum Vacuum ______ in. Hg

Ref. WTM Ser. # 19598 Calibrated By Joseph C. Sanders

	RUN #		1	2	3	4	5
01	ΔH (DGM)		0.50	1.0	2.0	3.0	4.0
02	Δ WTM		0.8	0.90	1.2	1.45	1.75
03	Gas Vol Wet Test Meter	Initial	200.000	215.000	36.000	57.000	74.000
04		Final	215.000	235.000	56.000	73.000	90.000
05	Gas Vol Dry Gas Meter	Initial	165.900	181.685	203.085	224.292	241.378
06		Final	181.160	202.071	223.314	240.377	257.389
07	Temp °F Wet Test Meter	Initial	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80
08		Final	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80
09	Temp °F Dry Gas Meter	Initial	In 81 Out 89 Avg. 85	In 95 Out 88 Avg. 91.5	In 96 Out 88 Avg. 92	In 98 Out 89 Avg. 93.5	In 98 Out 89 Avg. 93.5
10		Final	In 95 Out 88 Avg. 91.5	In 96 Out 88 Avg. 92	In 98 Out 88 Avg. 93	In 100 Out 89 Avg. 94.5	In 90 Out 101 Avg. 95.5
11	P_{bar} in. Hg		29.75	29.75	29.75	29.75	29.75
12	Time (sec)		2340	2193	1554	1022	881
Meter Correction Factor			0.9948	0.9977	1.0036	1.009	1.011
Q_m			0.3915	0.5567	0.7846	0.9540	1.1052
K_m			0.6930	0.6969	0.6946	0.6896	0.6920
ΔH_a			1.92	1.90	1.91	1.94	1.92

Averages: Y = 1.003 ΔH_a = 1.92

AD-A099 527 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CT F/G 13/2
TEST AND EVALUATION OF THE TRECAN INCINERATOR.(U)
MAR 81 M D LAYNE
UNCLASSIFIED CGR/DC-3/81 NL

2 of 2

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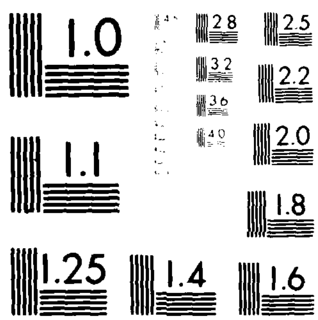


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

METER CALIBRATION FORM - DGM

Date December 26, 1979 Box No. C-133

Test Conditions: ΔH .5-1-2-3-4 in. H_2O Maximum Vacuum 0 in. Hg

Ref. DGM Ser. # ____________ Calibrated By ____________

	RUN #						
01	ΔH (DGM)		0.5	1.0	2.0	3.0	4.0
02	Y (Ref. DGM)		1.007	1.007	1.007	1.007	1.007
03	Gas Vol Ref. DGM	Initial	612.224	642.102	652.110	662.455	682.563
04		Final	641.838	651.743	661.765	672.377	692.335
05	Gas Vol Dry Gas Meter	Initial	128.326	159.303	169.720	180.432	201.110
06		Final	159.027	169.342	179.725	190.639	211.118
07	Temp °F Ref. DGM	Initial	In Out Avg. 53	In Out Avg. 59	In Out Avg. 60	In Out Avg. 61	In Out Avg. 62
08		Final	In Out Avg. 59	In Out Avg. 60	In Out Avg. 61	In Out Avg. 61	In Out Avg. 62
09	Temp °F Dry Gas Meter	Initial	In 101 Out 64 Avg. 82.5	In 110 Out 73 Avg. 91.5	In 96 Out 75 Avg. 85.5	In 98 Out 76 Avg. 87	In 93 Out 77 Avg. 85
10		Final	In 109 Out 73 Avg. 91	In 111 Out 74 Avg. 92.5	In 114 Out 75 Avg. 94.5	In 110 Out 76 Avg. 93	In 114 Out 77 Avg. 95.5
11	P_{bar} in. Hg		30.09	30.09	30.09	30.09	30.09
12	Time (sec)		4849	1153	831	696	599
Meter Correction Factor			1.0280	1.0251	1.0218	1.0258	1.0264
Q_m			0.3935	0.5360	0.7442	0.9076	1.0388
K_m			0.7008	0.6744	0.6617	0.6606	0.6541
ΔH_a			1.8752	2.0248	2.1031	2.1103	2.1523

Averages: Y = 1.025 ΔH_a = 2.053

METER CALIBRATION FORM - WTM

Date March 20, 1980 Box No. LSI-460

Test Condition: $\overline{\Delta H}$ ______ in. H_2O Maximum Vacuum ______ in. Hg

Ref. WTM Ser. # 19598 Calibrated By Joseph C. Sanders

	RUN #		1	2	3	4	5
01	ΔH (DGM)		0.50	1.0	2.0	3.0	4.0
02	ΔWTM		0.8	0.90	1.2	1.45	1.75
03	Gas Vol Wet Test Meter	Initial	200.000	215.000	36.000	57.000	74.000
04		Final	215.000	235.000	56.000	73.000	90.000
05	Gas Vol Dry Gas Meter	Initial	165.900	181.685	203.085	224.292	241.378
06		Final	181.160	202.071	223.314	240.377	257.389
07	Temp °F Wet Test Meter	Initial	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80
08		Final	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg. 80	In Out Avg 80
09	Temp °F Dry Gas Meter	Initial	In 81 Out 89 Avg. 85	In 95 Out 88 Avg. 91.5	In 96 Out 88 Avg. 92	In 98 Out 89 Avg. 93.5	In 98 Out 89 Avg. 93.5
10		Final	In 95 Out 88 Avg. 91.5	In 96 Out 88 Avg. 92	In 98 Out 88 Avg. 93	In 100 Out 89 Avg. 94.5	In 90 Out 101 Avg. 95.5
11	P_{bar} in. Hg		29.75	29.75	29.75	29.75	29.75
12	Time (sec)		2340	2193	1554	1022	881
	Meter Correction Factor		0.9948	0.9977	1.0036	1.009	1.011
	Q_m		0.3915	0.5567	0.7846	0.9540	1.1052
	K_m		0.6930	0.6969	0.6946	0.6896	0.6920
	ΔH_a		1.92	1.90	1.91	1.94	1.92

Averages: Y = 1.003 ΔH_a = 1.92

METER CALIBRATION FORM - DGM

Date . July 17, 1980 Box No. LSI-460

Test Condition: $\overline{\Delta H}$ 2.0 in. H_2O Maximum Vacuum 10 in·Hg

Ref. DGM Ser. # 151 7662 Calibrated By John Rogers

	RUN #		1	2	3		
01	ΔH (DGM)		2.0	2.0	2.0		
02	Y (Ref. DGM)		1.035	1.035	1.035		
03	Gas Vol	Initial	924.477	935.435	952.023		
04	Ref. DGM	Final	935.435	952.023	968.784		
05	Gas Vol	Initial	809.143	820.224	837.014		
06	Dry Gas Meter	Final	820.224	837.014	853.902		
07	Temp °F	Initial	In Out Avg. 75	In Out Avg. 75	In Out Avg. 75	In Out Avg.	In Out Avg.
08	Ref. DGM	Final	In Out Avg. 75	In Out Avg. 75	In Out Avg. 75	In Out Avg.	In Out Avg
09	Temp °F	Initial	In 86 Out 80 Avg. 83	In 86 Out 80 Avg. 83	In 86 Out 80 Avg. 83	In Out Avg.	In Out Avg.
10	Dry Gas Meter	Final	In 86 Out 80 Avg. 83	In 86 Out 80 Avg. 83	In 86 Out 80 Avg. 83	In Out Avg.	In Out Avg.
11	P_{bar} in. Hg		30.06	30.06	30.06		
12	Time (sec)		900	900	900		
Meter Correction Factor			1.034	1.033	1.038		
Q_m							
K_m							
ΔH_a							

Averages: Y = 1.035 ΔH_a =

METER CALIBRATION FORM - DGM

Date July 17, 1980 Box No. C-133

Test Condition: $\overline{\Delta H}$ 1.0 in. H_2O Maximum Vacuum 5 in·Hg

Ref. DGM Ser. # 151 7662 Calibrated By John Rogers

	RUN #		1	2	3		
01	ΔH (DGM)		1.0	1.0	1.0		
02	Y (Ref. DGM)		1.035	1.035	1.035		
03	Gas Vol Ref. DGM	Initial	982.114	992.228	001.902		
04		Final	992.228	001.902	014.248		
05	Gas Vol Dry Gas Meter	Initial	348.526	359.002	369.165		
06		Final	359.002	369.165	381.911		
07	Temp °F Ref. DGM	Initial	In Out Avg. 75	In Out Avg. 75	In Out Avg. 75	In Out Avg.	In Out Avg.
08		Final	In Out Avg. 75	In Out Avg. 75	In Out Avg. 75	In Out Avg.	In Out Avg
09	Temp °F Dry Gas Meter	Initial	In 110 Out 78 Avg. 94	In 110 Out 89 Avg. 99.5	In 110 Out 90 Avg. 100	In Out Avg.	In Out Avg.
10		Final	In 110 Out 89 Avg. 99.5	In 110 Out 90 Avg. 100	In 112 Out 90 Avg. 101	In Out Avg.	In Out Avg.
11	P_{bar} in. Hg		30.06	30.06	30.06		
12	Time (sec)		900	900	900		
	Meter Correction Factor		1.037	1.028	1.047		
	Q_m						
	K_m						
	ΔH_a						

Averages: Y = 1.035 ΔH_a =

TEMPERATURE CALIBRATIONS

BOX NO. - LSI 460   Model No. - 2572-X-1-P-X-K-F   Serial No. 941652

PRETEST

DATE 3/20/80

Ref. Temp.	Stack	Probe	Hot Box	Impinger	Dry Gas Meter In	Dry Gas Meter Out
34	35	34	34	33	34	34
75	74	75	76	75	75	75
160	161	161	159	160	160	160
210	210	211	211	212	211	211
398	400	399	398	400	399	399
510	509	511	509	512	510	510

TEMPERATURE CALIBRATIONS

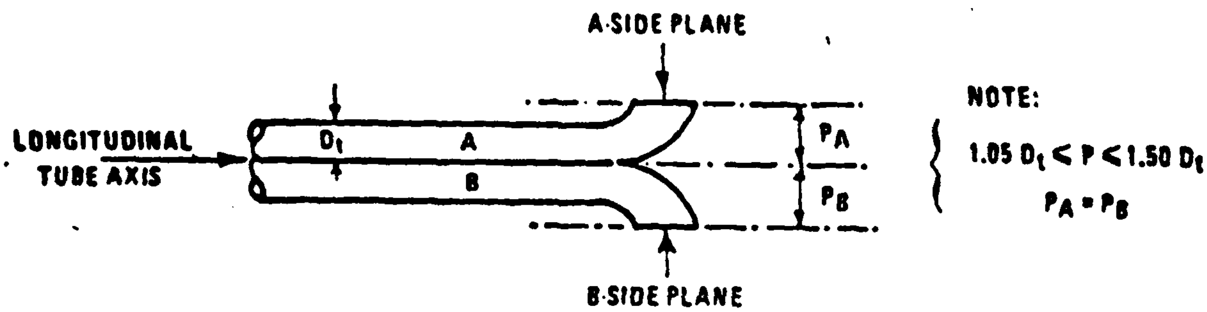
BOX NO. C-133 Model No. Serial No.

PRETEST

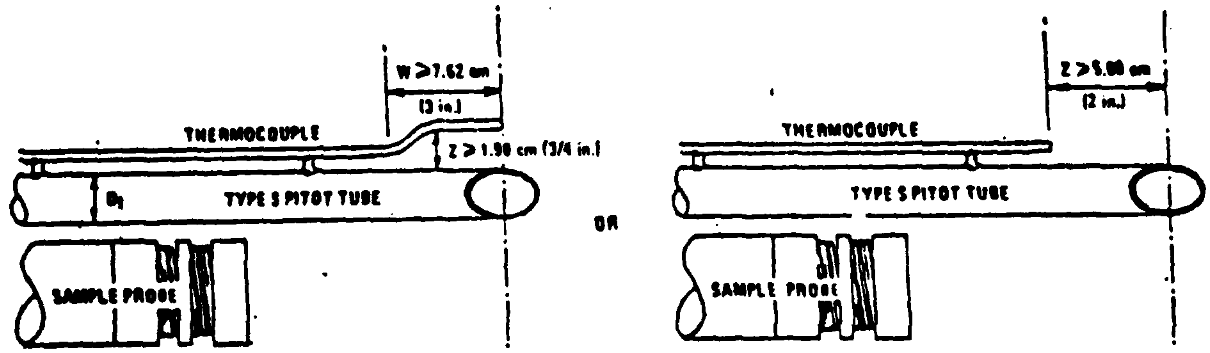
DATE 3/20/90

Ref. Temp.	Stack	Hot Box	Impinger	Dry Gas Meter	
				In	Out
33	35	34	34	34	34
75	75	75	74	74	74
168	165	167		167	168
210	210	212			
370	370	368			
495	498				

PROBE #3 - 10 ft DATE 11-26-79

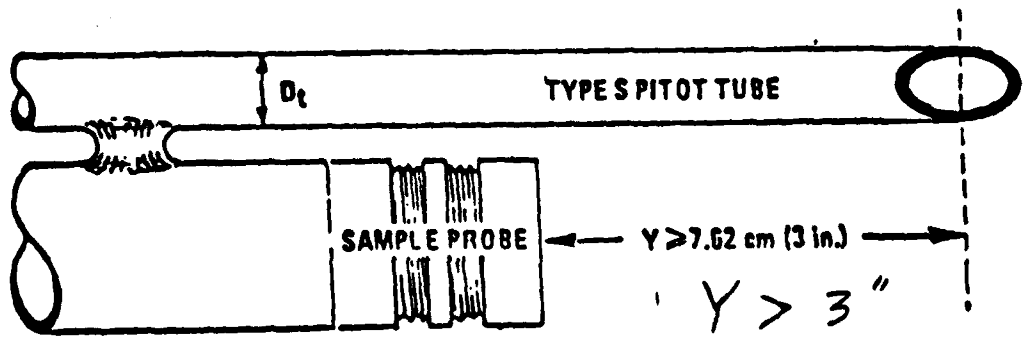


$P_A = P_B$ $1.05\ D_t < P < 1.50\ D_t$



Z > 2"

Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

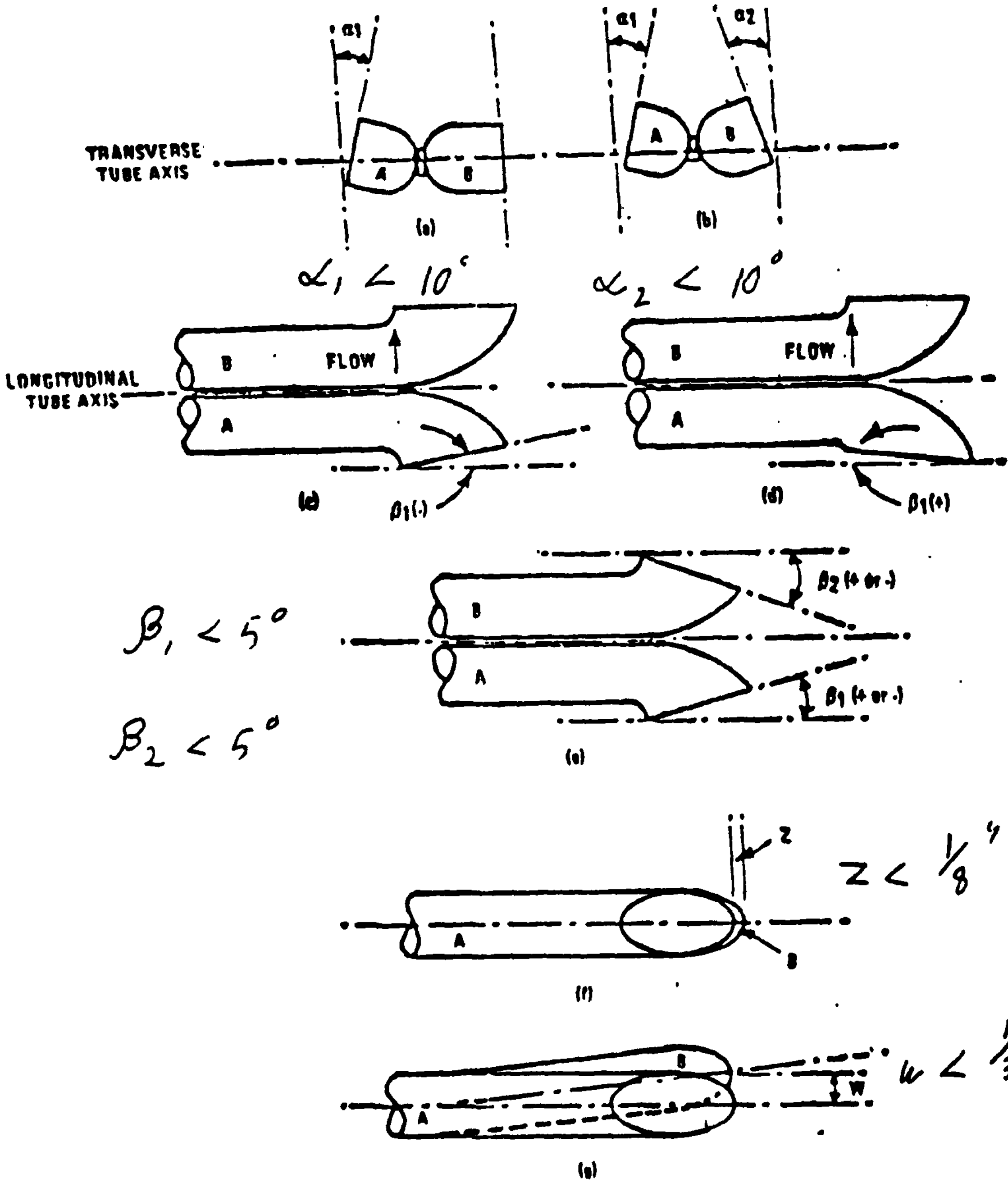


Y > 3"

Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

PITOT CALIBRATIONS

PROBE #3 - 10 ft DATE 11-26-79



$\alpha_1 < 10°$ $\alpha_2 < 10°$

$\beta_1 < 5°$

$\beta_2 < 5°$

$z < \frac{1}{8}''$

$w < \frac{1}{32}''$

Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}_{p(s)}$ so long as α_1 and $\alpha_2 < 10°$, β_1 and $\beta_2 < 5°$, $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).

APPENDIX D

Letter Describing Capabilities of the HH3F, HH52A, and HH65A Helicopters

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS
COMMANDING OFFICER
U.S. COAST GUARD
AVIATION TRAINING CENTER
MOBILE, ALABAMA 36608

13010
18 March 1980

From: Commanding Officer, CG Aviation Training Center
To: Commanding Officer, CG Research & Development Center

Subj: HH-3F, HH-52A & HH65A; Capabilities for incinerator transport

Ref: (a) CO, CG R & D Center ltr 704153.4.1 of 26 Dec 79

1. In response to reference (a) the enclosed information has been prepared for your use in determing the capability of CG helicopters transporting the various components of the Trecan LTD incinerator.

2. The HH-52A and the HH65A (new SRR) helicopters are totally out of the question for the following reasons:

a. The HH-52A has a max gross weight of 8300 lbs which is approximately 250 lbs less than the combined weight of the aircraft, crew, and 2000 lb load, not including any fuel.

b. The HH65A with crew and a 2000 lb load totals 300 lbs less than the max gross weight of the aircraft which would be a good fuel reserve but that's all.

The HH-3F helicopter is the only remaining possibility and would be well suited for the mission, subject to the limitations as discussed in enclosure (1). This enclosure also contains performance data that relate to fuel required and fuel available for given flight conditions. For example, on a standard day (i.e. 15^{o} C OAT, pressure and density altitude at sea level) with 10 kts of wind at the pickup and assembly sites an HH-3F could make three round trip shuttles a distance of five miles, one way, before needing to refuel. If working in the same area for both pickup and assembly phases the HH-3F could operate for one and one-half hours, given the same conditions, before needing to refuel. In each case, a refueling source would have to be close by or this would necessarily take away from fuel available for the mission.

18 March 1980

Subj: HH-3F, HH-52A & HH65A; Capabilities for incinerator transport

3. In addition to the discussion in enclosure (1) of the inflight stability of external loads we recommend contacting the experts in the field, namely the U.S. Army Transportation School at Fort Eustis, Virginia for further guidance in this phase of your evaluation. Correspondence should be addressed as follows: Directorate of Training, U.S. Army Transportation School, Fort Eustis, Virginia 23604 (ATSP-DT-TM).

4. Finally, in an effort to develop a realistic test plan and evaluation for this project we recommend you contact COMDT (G-OSR-2) for the assignment of an air station to assist you. This will bring you in direct contact with not only the aircraft but also the aviation personnel who, at some stations, routinely operate with external loads.

H. F. ORR
By direction

Encl: (1) Discussion of HH-3F Capability and Attachments (1), (2) and (3)

Copy to:
COMDT (G-OSR-2)

DISCUSSION OF HH-3F CAPABILITY

1. The following is a discussion of the HH-3F's capability to sling load sections of the Trecan LTD's portable incinerator. An analysis of the tactical data for the HH-3F will show that a mission of this nature is very much within the capability of this helicopter, however this capability is definitely limited by the concepts and principles presented in the following discussion.

2. The recommended and preferred method of transporting this equipment is externally vice internally for the following reasons:

a. Most importantly, the single engine capability of the aircraft would be greatly enhanced, should the situation arise, by being able to jettison the external load at a moment's notice. This would mean an immediate reduction of up to 2000 lbs of weight from the gross weight of the aircraft thereby placing the helicopter well within the single engine flight regime for all calculated conditions up to a pressure altitude of 1000 ft.

b. Since this equipment requires either a high lift crane or a medium lift helicopter for assembly and the location of assembly would most likely be a remote area, the external method would be more efficient.

c. The actual handling of the equipment in the transportation phase is greatly reduced utilizing the external method. Hook up and delivery of a properly prepared sling load is a simple and safe task when reasonable safety precautions are followed. Loading and unloading heavy and unwieldy objects like the incinerator sections internally is laborious, hazardous to the aircraft and personnel, and an egress hazard in the event of inflight emergency. Attachment (1) addresses the inflight stability of sling loads, pointing out some important considerations to follow when actually rigging the items for flight.

d. Aircraft weight and balance, and therefore preflight planning, is greatly simplified using external loads due to the fact that the load is suspended directly beneath the aircraft's main transmission, i.e. directly below the lift vector for the rotor system of the helicopter. The weight of the load as opposed to a moment affecting the center of gravity of the aircraft is the primary consideration - providing the load is riding well in forward flight.

3. The major drawbacks to external loads are the reduced range of transportation due to the slow airspeeds needed to keep the load steady, and a reduction in the maximum weight the helicopter can lift because it has to hover out of ground effect when making the pickup/delivery. The former can only be predicted by actual test flights, for the most part, although to get an idea of fuel consumption for missions involving different enroute distances attachment (2) has been prepared. The total fuel values derived in this attachment are based upon estimated fuel flows for the various phases of the flight. Also included in the calculations are a set of standard conditions, all of which are identified. As mentioned before, the importance of the arrangement of the load and the manner in which the sling apparatus is attached cannot be overemphasized. This greatly affects how well the load will ride in forward flight and consequently what kind of range the aircraft will possess. Not to be overlooked is the actual shape of the object and whether or not it possesses any aerodynamic characteristics. This will also affect the range of the aircraft by how well the load streamlines. The information contained in attachment (1) will necessarily have to be considered if during the test phase any of these adverse effects relating to the transport of external loads are to be minimized.

Generally speaking, the capability to lift a heavy load in the HH-3F is limited by power being applied to the aircraft transmission, in cold temperatures; and by how much power the engines can produce in warm temperatures. With the use of flight test and estimated aircraft performance data fairly reliable values can be calculated to predict aircraft performance under varying conditions. Attachment (3) has been prepared to show the effects of temperature and wind on the HH-3F's capability to lift a 2000 lb external load and the resultant fuel load that could be carried for the different phases of the flight. The effects of wind are not normally considered in the preflight planning of external load missions except to note that any wind encountered may serve to improve helicopter performance. For maximum power maneuvers a power safety factor of 10% torque is required between power required and power available and is figured into the calculations of attachment (3). Normally if this safety margin does not exist the mission should not be attempted. Due to the height, above the ground, of the hovering helicopter when it picks up the external load, all performance calculations are based on the aircraft being out of ground effect. This height will obviously vary from mission to mission but is generally directly dependent on the length of the pendant used to suspend the load. This phenomenon, known as ground effect, is a cushioning that the aircraft experiences while hovering at low heights above the ground, usually within one rotor diameter distance (up to 40 to 60 ft for the HH-3F depending on gross weight), and when in this effect, significantly less power is required to hover for a constant gross weight of aircraft.

4. In comparing fuel data between attachments (2) and (3) one can readily see the HH-3F is not going to be overly effective at making long enroute distances with 2000 lb external loads. For even the shortest distances it would be virtually impossible for the HH-3F to transport these items on a single fuel load without taking the time to refuel. If worked in a common area for both pickup and assembly, the HH-3F would be very useful and could probably complete an entire assembly phase without refueling, providing there were no lengthy delays and the winds were favorable.

In many respects, the data reveals a very underestimated look at the HH-3F as pertains to transporting a 2000 lb external load. First, it assumes the hovering portions of the evolution will be accomplished hovering out of ground effect (HOGE) with the associated increases in power required. As mentioned before, this is not altogether true and depends on the length of the sling apparatus and how high the pilot elects to perform the hover. With proper equipment and operating technique this lost performance can be minimized. Secondly, the slightest amount of wind tends to increase helicopter performance significantly, and if continuous operation is anticipated in any one area (i.e. pickup and assembly site co-located) this could be used to one's advantage. Last of all, there exists a significant difference in weight between what full maximum power (MAX GW-HOGE) and what the safety factored power (GW-HOGE) will hover out of ground effect. A comparison of these weights in each category shows this power safety factor severely limits the aircraft's potential for handling a larger load.

The planning and execution of external load missions involves many variables and necessitates the inclusion of various safety factors that help insure the mission goes as planned. Basically all safety factors boil down to planning very conservatively thereby allowing plenty of reserve to draw from in case unforeseen circumstances are encountered.

CHAPTER 3
IN-FLIGHT STABILITY OF SLING LOADS

3-1. Theory of Stabilizing Sling Loads

a. The aerodynamic phenomena of side to side movement and forward-aft oscillation of cargo suspended beneath a helicopter show that the pilot is flying two different bodies: One is the helicopter, which is aerodynamically stable; the other is the sling load, which seldom is aerodynamically stable. Therefore, most of the problems encountered in helicopter external lifts concern the instability of loads in flight.

b. Load instability will occur whenever the weight of a suspended load is not sufficient to *hold it down against the drag of the air through* which it moves. It is commonly experienced with elongated loads that are symmetrical about their CG's. Such loads will always turn broadside to the direction of flight, thus exposing maximum drag surface. The lighter the load in proportion to the exposed drag surface, the lower is the airspeed at which instability will occur. Stabilization of such loads may be assured by one or more of the following means:

(1) Reducing the airspeed of the helicopter.

(2) Increasing the weight of the load.

(3) Reducing the drag surface by altering the relationship between the CG and the center of pressure of the suspended load in such a way as to assure that the narrowest surface points in the direction of flight.

c. Normally, the drag-surface-reduction means is the preferred solution. This effect is achieved either by adding surface to the rear of the load or by adding weight to the front. The general rule is that stability will be assured at practical *helicopter speeds when the load's CG is located* at the front third of the surface area.

d. While it is true that a load may be stabilized by reducing the airspeed, this means should be used only as a last resort. Any airspeed below approximately 60 knots will severely degrade the pilot's opportunity to jettison the load and perform an autorotational landing in the event of power failure. For this reason, the rigging procedures for all tactical loads should be based on the requirement to fly the loads at speeds in excess of 60 knots. When this rigging criterion cannot be met, appropriate cautionary steps should be taken during flight of the load. For example, a small CONEX container may be flown at 60 knots when its total weight exceeds 2,500 pounds. When the container is flown empty, however, severe instability will occur at about 30 to 40 knots of airspeed.

3-2. Examples of Load Stabilization

a. There are two expedient means of stabilizing sling loads. One is by adding surface to the rear of the load. In this concept, the added surface consists of related equipment of light density such as connecting a trailer to the vehicle to be lifted. Since the amount of additional surface is out of proportion to the weight that has been added, the relationship between the CG and center of pressure of the total load has been altered and the load tends to stabilize in flight. The addition of related equipment is a more practical technique than that of installing rigid fins or similar airfoil spoilers onto the rear of the load.

b. Another means of stabilizing a sling load is by adding weight to the *front of the load. In* this concept, supplies of high density are secured to the front end of the load. Since the amount of additional weight is out of proportion to the amount of surface that has been added, the relationship between the CG and center of pressure of the total load has been altered and the load tends to stabilize in flight. While this basic concept is simple, its mathematical application under field conditions is complex because the amount of weight to be added must be cal*culated in moments* rather than raw weight. The desired balance location is a point at which not more than one-third of the total surface will be located forward of the CG. Weight must be added so as to cause the moment of the forward one-third to equal the moment of the rear two-thirds of the load. This value can be mathematically calculated by the same methods used to determine the balance of a loaded aircraft. A suitable system that will usually be more satisfactory under field conditions can be employed by using figure 3-1 as a guide.

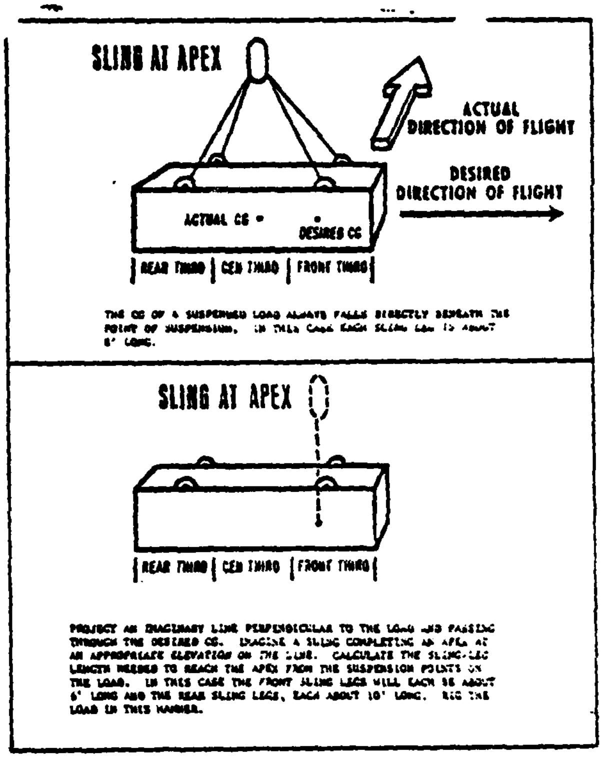


Figure 3-1 (1). Instructions for rigging a typical sling load to assure its in-flight stability.

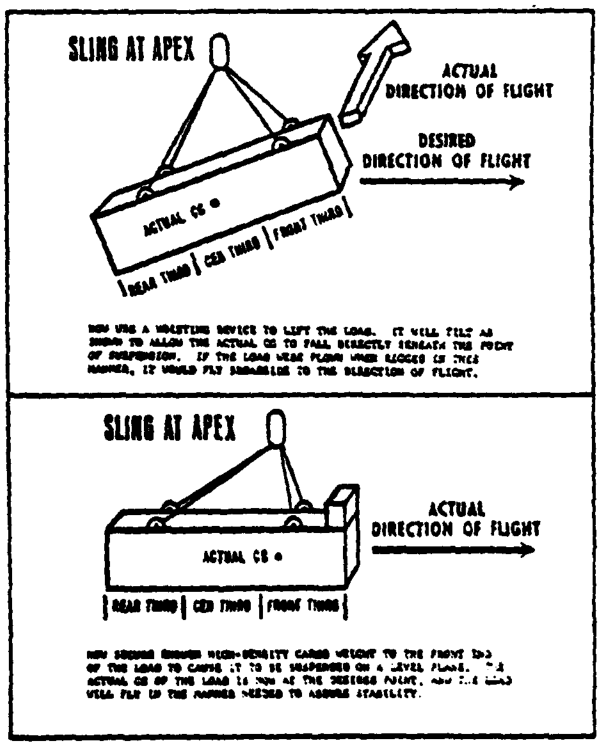


Figure 3-1 (2). Instructions for rigging a typical sling load to assure its in-flight stability.

In this example, the typical configured load is 12 feet by 3 feet by 1 foot, weighs 600 pounds, is symmetrical about its CG, and will alwa fly broadside to the direction of flight.

PERFORMANCE DATA (RANGE VS FUEL)

Constants:

- Standard day (15°C OAT, pressure altitude 0)
- No wind
- Enroute altitude 1000 ft (PA)
- Fuel reserve 20 to 30 minutes (400 lbs)
- Start/taxi fuel 100 lbs
- Pickup hover 120 lbs (5 min at 1450 lbs/hr)
- Terminal hover 240 lbs (10 min at 1450 lbs/hr)
- Enroute trip 920 lbs/hr (72 KTAS)
- Return trip 1040 lbs/hr (110 KTAS)

Fuel (lbs)	Distance One Way (NM)			
	5	10	30	60
Start/taxi	100	100	100	100
Pickup	120	120	120	120
Enroute	64	127	383	765
Assembly	240	240	240	240
Return	47	95	285	570
Reserve	400	400	400	400
Total	971	1082	1528	2195

Considerations:

All fuel flow rates used in these computations are estimates based on the best available data. As a flight progresses more and more fuel is being consumed thereby reducing aircraft weight, and hence, similarly reducing the power requirement for the same amount of work being performed. As the mission progresses less fuel will be required for each evolution. The above data does not take this into account to any great degree.

The hover times for both pickup and assembly phases of the evolution are also best estimates being rather certain of the former and not so with the latter. The study utilizing the Bell helicopter commented on some rather lengthy delays during installation and it is this sort of thing that really eats up mission time and necessitates early aircraft refueling.

The enroute airspeed of 72 knots true airspeed was used because it was the lowest airspeed which would produce any fuel flow infomation from the cruise performance charts. This is significant because it is strictly an estimate of how fast the external loads could be flown with. Actual flight test data will definitely be needed if a comprehensive study on external load transport of these items will be feasible over greater distances.

PERFORMANCE DATA (WEIGHT VS FUEL)

Constants:
Aircraft operating weight - 17,353 lbs. (includes a typically SAR equipped H-3, 2 pilots, 2 crew, cargo sling, and 2000lb external load)
Pressure altitude - sea level

Variables:
Temperature (density altitude)
Wind

I. Temp - 5°C OAT, DA -1100ft.

	NW	10KTS	15KTS
PWR AVAIL	119	121	121
Q-HOGE	93	93	93
GW-HOGE	18,800	19,550	20,500
MAX GW-HOGE	20,150	21,400	22,050
FUEL	1447	2197	3147

II. Temp - 15°C OAT, DA 0

PWR AVAIL	110	117	117
Q-HOGE	93	93	93
GW-HOGE	18,800	19,550	20,450
MAX GW-HOGE	20,100	21,400	22,050
FUEL	1447	2197	3097

III. Temp - 25°C OAT, DA +1100ft.

PWR AVAIL	100	107	107
Q-HOGE	90	93	93
GW-HOGE	18,300	19,450	20,300
MAX GW-HOGE	19,950	21,000	22,050
FUEL	947	2097	2947

IV. Definitions:
Power available - % torque (power) available from the engines
Q-HOGE - the maximum power that can be used for flight planning purposes (which is 10% torque less than either power available or transmission limit) to hover the helicopter with the load out of ground effect
GW-HOGE - that gross weight of helicopter (including fuel) that the Q-HOGE figure corresponds to
MAX GW-HOGE - the maximum helicopter weight that can be hovered, out of ground effect, disregarding the 10% safety factor
FUEL - difference between aircraft operating weight and GW-HOGE (fuel that could be carried for the mission)

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